STUDY OF THE INDIVIDUAL WORKER'S PRODUCTIVITY RANGE

A THESIS

Presented to

the Faculty of the Division of Graduate Studies

Georgia Institute of Technology

In Partial Fulfillment

of the Requirements for the Degree

Master of Science, Undesignated

by

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September 1950

STUDY OF THE INDIVIDUAL WORKER'S PRODUCTIVITY RANGE

Approved:

Date Approved by Chairman Sept. 4, 1950

ACKNOWLEDGMENTS

On completion of this work I wish to express my sincerest thanks to Professor Joseph S. Dwyer, not only for his aid in deciding the problem to be studied, but also for his valuable assistance and guidance in its prosecution. This expression of appreciation is expanded to include Mr. Robert Carson, for his contribution, and those students who served as subjects for the card dealing experiments.

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I

INTRODUCTION

General. The effect of numerous variables on the performance characteristics of individual workers has become a matter of great importance since the introduction of scientific management to the industrial world near the end of the nineteenth century. It was early recognized that the most pressing need would be the elimination or the minimizing of all barriers to the continuous performance of the individual worker. The combined efforts of motion-time engineers and industrial psychologists have done much to remove barriers and to clarify the magnitude of the overall problem. The full measure of the total individual difference effects may never be wholly established.

It appears that there is much current disagreement among the various authorities as to the relative importance of the numerous factors that influence productive effort and contribute to improved efficiency or create greater inefficiency. Sylvester[1] inferred that the lack of statistical data and associated information prevents conclusive deductions and makes it necessary to grope in a general way for an inkling of the true relationships.

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[1] L. A. Sylvester, The Handbook of Advanced Time-Motion Study (New York: Funk and Wagnalls, 1950) p. 80.

Wechsler[2] has defined the range of human capacity as the difference in ability or in the magnitude of the trait which separates the highest from the lowest; the least efficient from the most efficient. The full impact of the "range" problem is contained in those differences.

Tools and methods for the measurement of the productive range vary from the rule-of-thumb method to the more complex mathematical and statistical methods. Many of these techniques can never be adopted for use by the observer at the stop-watch level but must be retained for improvement and use by the more expert. Transformation of all possible data to terms of usefulness at the application level is considered a worthy objective for all.

Time study techniques normally entail the measurement of time required for performance of elemental job operations and the comparison of the operator's performance with that of the "average" operator. No means has yet been devised by which the performance of the "average" operator can be fixed so it is necessary for the observer to rate each operator against a hypothetical performance. Thus it can be seen that no absolute average performance can be indicated so there is no means by which the absolute accuracy of performance ratings can be assured.

Problem. The need for time study data is basic for the establishment and maintenance of incentive-wage plans. Time study techniques are based on recognition of the existence of a performance range and

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[2] David Wechsler, The Range of Human Capacities, The Scientific Monthly, Vol. XXXI, pp. 35-39, July, 1930.

this concept is narrowed to the assumption that the "normal" or average time exists at some point within that range.

Since the performance range is variable the overall scale was assumed to be a series of related distribution curves. It was the designated purpose of this thesis to investigate those distribution curve relationships.

Accordingly, a series of simulated-work tests were conducted at certain designated speeds all of which could be attained by all subjects. The card dealing operation was chosen because of its simplicity and for the ease with which sufficient skill can be attained for dependable results.

Deal tempos chosen included fastest, incentive, normal, free choice and slowest. Even though there may be other definite intermediate performance speeds these were thought to be sufficient for the purpose of this thesis.

Other investigators have exploited card dealing as a source performance data. Carroll has advocated that the "normal" time for dealing four thirteen-card hands is .45 minutes whereas Presgrave[3] found that the fastest deal times vary from .35 to .40 minutes from which he computed the "normal" deal time .50 minutes.

Chapter II of this thesis is devoted to the discussion of the overall range of human productivity as revealed by the literature of

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[3] Ralph Presgrave, The Dynamics of Time Study (New York: McGraw-Hill Book Co. Inc., 1945) p. 165.

numerous leading authorities in the time study and industrial psychology fields.

Individual differences which contribute to the spread of the effort range, from an operational standpoint, are given coverage in Chapter III. The value of training for negation of individual differences is covered at length.

Chapter IV presents a brief discussion of individual differences from the personal rather than the operational standpoint. The magnitude of the problem of appraising the effects of fatigue is also covered in this chapter.

Chapter V shows the practical application of certain techniques to original raw data. The results show rather clearly the bases for differences of opinions and why many of the pertinent questions remain unanswered. The tabulated time values have not been modified or leveled in any way.

Definitions. For the purpose of this thesis the following obtain:

1. The term "effort" is defined as the expenditure of energy for manual performance.
2. The term "skill" is defined as the degree to which speed of motion and motion patterns are combined for productive purposes.
3. The phrase "range of productivity" is defined as the difference in times required by the slowest and fastest performers in the application of skill and effort and may be expressed as a ratio.

II

PRODUCTIVE EFFORT AND ITS MEASUREMENT

The systematic application of effort for the attainment of maximum productivity is generally considered the foundation on which scientific management rests. Accomplishment of this objective is sought through the reduction of wasted effort to its minimum compatible level and the scientific direction of all constructive effort so as to gain maximum output for the energy expended during work periods.

Methods by which the elements of work performance are evaluated frequently differ significantly depending upon the authority being emulated. All of the systems are dedicated to the same principal objective but are too often in disagreement as to the exact relationship and importance of the elements to be measured and as to the techniques for correct measurement. It is unlikely that performance ratings established by two observers applying different methods for the same operation will be in exact agreement and it would be just as uncommon for such ratings by two observers using the same method to be identical. Even though all of the methods have a "time" base the lack of agreement as to the correct weightings for measurable and assessible properties and the divergence of opinion among the experts have no doubt been deterrent to more widespread investigation of the range of worker productivity.

Presgrave has deplored the existence of so many divergent

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[1] Ralph Presgrave, The Dynamics of Time Study (New York: McGraw-Hill Book Co., Inc., 1945) p. 8.

Methods as have done other recognized leaders interested in correct measurement techniques. Gomberg[2] has asserted that, with few exceptions, little effort has been made to examine the basic foundations of the various time study procedures. He cited Presgrave's analysis of the situation as the only real attempt to view time study critically.

It is likewise regrettable that the chief medium for the motivation of effort is of a monetary nature since it contributes a severe deterrent to the true expression of the individual's full capability within the performance range. It is generally acknowledged that, in unmotivated group performances, the individual performance times gravitate towards that of the slowest operator rather than toward the potential average for the group.

Recognition of this character trait in the worker prompted Taylor[3] to develop and install his Differential Piece-rate System in several labor operations at the Bethlehem Steel Company just prior to 1900. The job of manually loading 92-pound pigs of iron onto railroad cars afforded an opportunity for a classic application of the system. Study and analysis of the problem convinced Taylor and associates that the daily loading rate should be 47 long tons per worker instead of the 12 1/2 tons then accepted as standard. Through careful worker selectivity, high incentive pay rate per ton, and regulated rest and work periods

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[2] W. A. Gomberg, A Trade Union Analysis of Time Study (Chicago: Science Research Assn., 1948) p. 3.

[3] F. W. Taylor, Scientific Management (New York: Harper and Bros., 1947) p. 42.

the newly projected high performance rate was achieved and maintained in disposing of 80,000 tons of pig iron. The ratio of the new rate to the old was 3.75:1.

Another project, designated and prosecuted at Taylor's direction, that of manually shoveling steel-making ingredients, produced similar results. After experimentation had revealed that a 21-pound shovel load was the most economical from the manpower standpoint the production rate was increased from 16-tons to 59 tons per worker, daily; a ratio of 3.69:1. The success of this venture, like its predecessor, was in a measure influenced by selected workers performing the one-best way under carefully regulated work conditions for high incentive pay.

From the practical industrial standpoint these two examples well illustrate the possible spread that is likely to exist between performance rates of the most efficient and the least efficient workers. Since Taylor advocated rigid worker selectivity and carefully regulated rest periods, the high performance rate has to be discounted as representing an average-worker performance.

Barnes'[4] report on the performances of 121 well trained semi-automatic lathe operators performing identical operations, for a one-day period, showed an average output rate of 72 pieces per operator, between range limits of 51 and 104 pieces. Only 54 of the operators or 45 per cent of the group were able to equal or exceed that average. The conditions under which the study was made were considered most favorable

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[4] R. M. Barnes, Motion and Time Study, (New York: John Wiley and Sons, Inc., 1949) p. 353.

for uninhibited performances, making valid results possible. The range of productivity was thus observed to be 2.04:1; the ratio of the best to the poorest.

In evaluating the results of extensive test data, Wechsler[5] concluded that the range of most group physical and mental activities vary as 2:1; the ratio of the highest to the lowest. He cautioned that some authorities reject this ratio in favor of higher ones.

The range of motor capacities, compiled by Wechsler from the tests previously mentioned, shown below is a partial listing of the data on which his conclusion was based:

RANGE OF MOTOR CAPACITIES

Trait or Ability	Range Ratio
Extension of wrist	1.65:1
Speed of inserting bolts	2.09:1
Stringing discs	2.12:1
Flexion of the wrist	2.18:1
Simple reaction time	2.24:1
Card sorting	2.50:1
Median ratio	2.23:1
Mode ratio	2.17:1

He pointed out that defined motion control will often narrow the spread between the highest and lowest time rates. This is based on the assertion that a below-average operator, performing an operation with time-wasting motions, has not only his natural slowness to bring his performance well below that of the fast worker but is pulled still lower by inefficiency of the method used.

[5] David Wechsler, The Range of Human Capacities (Baltimore: Williams and Wilkins, 1935) p. 73.

In commenting on the familar spoon polishing test performed by a group of 26 workers, Wechsler cited the fact that after the slowest workers had been taught the more efficient method the ratio became less than 2:1, instead of the previous high 5:1 ratio.

Dipple[6] likewise recognized that the ratio of the fastest to the slowest performance times was 2:1. He asserted that, within the range of productive effort, maximum effort has a predetermined place in the scale but that the position of the "normal" performance is not so obvious. The "normal" performance or average worker performance is the criterion by which individual effort ratings are adjudged.

Sylvester[7], in a statistical approach to the solution of the problem, advanced the theory that the human being performs very much like a two-speed motor. The slow-speed pace is viewed as that of an inattentive, unmotivated or bored worker. Based on this assumption it can be readily seen that the statistical curve is of bimodal rather than uni-modal characteristic.

Data gathered from motion pictures of 46 unsuspecting unladen male subjects, chosen at random from those photographed walking along a city street, substantiated the bi-modal theory to Sylvester's satisfaction. One modal average, reportedly, developed at 3.10 to 3.25 miles per hour and another at 3.70 to 3.85 miles per hour.

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[6] S. B. Dipple, Time Study in Light Industry (Manchester, Eng.: Mechanical World Monograph, No. 27, 1946) p. 14.

[7] L. A. Sylvester, The Handbook of Advanced Time-Motion Study (New York: Funk and Wagnalls, 1950) p. 78.

Presgrave's attitude, regarding the records of output of a large group engaged in the performance of identical work, was that those records may not represent their true relative capacities. He intimated that such records indicate their potential productive abilities modified by a composite of forces; that is, individual differences. He stated that accumulating evidence points to the fundamental soundness of acceptance of the standard balanced frequency curve as representative of performance ranges and of the reasonable dependability of a 2.25:1 ratio for a single capacity such as effort. He qualified the term "effort" as meaning the speed of movement without accounting for the expenditure of energy or the effects of skill.

In commenting on the range of human capacities, this authority asserted that the matter of performance ranges had received too little attention and as a consequence more knoweldge was available on distribution. He acknowledged Wechsler's findings as the most noteworthy in that particular field.

In general, it appears that a high percentage of the authorities accept the 2:1 range ratio for general application.

III

INDIVIDUAL PERFORMANCE DIFFERENCES (OPERATIONAL)

The big problem of time study for the establishment of production standards is the evaluation of the time required for the normal or average person to perform his given task or job. This might be restated as--the setting of a performance "norm" for a given task. It is evident to all that the "norm" time lies at some point within the extreme limits of the range of productivity, although the exact location is not easily defined.

It is generally recognized that modification of recorded times is necessary to compensate for the relative productivity, with respect to normal, of the worker being observed. This makes the "norm" time a hypothetical value dependent upon the ability of the time study observer to adjudge the actual observed performance against his conception of a "normal" performance. All such decisions are, necessarily, conditioned upon the speed or rapidity of the operator's motions and the motion patterns used in the performance.

In his comments on the range of effort Presgrave[1] dwelt at length on the methods by which productivity of individual workers are evaluated. He pointed out that the many past and current methods, purportedly scientific, divide roughly into three main groups, namely:

1. The application of mathematical formulas.

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[1] Ralph Presgrave, The Dynamics of Time Study (New York: McGraw-Hill Book Company, 1945) p. 51.

2. The application of external correction factors derived from "leveling", "rating", etc.

3. The comparison of specific motion times with predetermined standard times.

Any or all of the techniques, whatever their classifications, must encounter and account for the wide variations in motion times and methods inherent in individual workers. The lack of stardardization of human beings makes the development of uniform standards for over-all application most problematical, if not impossible.

Presgrave's[2] dismissal of mathematical applications was predicated upon the failure of such methods to devote direct consideration to two of the major factors:

1. Workers' methods.

2. Speed of motions.

The application of external correction factors for the determination of the level of productive effort is generally accepted as the best substitute for the yet undeveloped perfect technique.

Under "rating" or "leveling" methods, differing interpretations and variations in measuring mediums are encountered which, coupled with differences in perceptive powers and judgment faculties of the observers, make uniform evaluation of performance times currently impossible of attainment. Gomberg's[3] discussion of the "normal" worker brings out many of these differences.

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[2]Ibid p. 52-3

[3]W. A. Gomberg, A Trade Union Analysis of Time Study, (Chicago: Science Research Associates, 1948) pp. 145-46.

Barnes[4] has said that the most important and the most difficult part of stop-watch time study is to evaluate the speed or tempo at which the person is working while the study is being made. Results of a simultaneous study, made by a group of nine experienced time study men, of the same operation shows conclusively the high degree of variation that can be expected in the time standards set by current time study methods. Each observer was permitted to use his accustomed method in rating the performance. Comparison of the results showed that recorded times varied from a low of .98 minutes to a high of 1.08 minutes. The average of the nine studies was 1.03 minutes from which the lowest and the highest values deviated by 5 per cent, each. The average performance "rating factor" for the group was 107 per cent which included a low of 100 per cent and a high of 110 per cent.

The short time element indicates that the operation under observation was, most likely, a relatively simple one. Operations of greater complexity may be expected to introduce greater deviation, to make the true measure of productive effort even more erroneous.

In another instance a program[5] designated to test as well as improve the judgment ability of time study personnel was conducted at the Honeywell plant of the Minneapolis-Honeywell Regulator Company, under the guidance of a qualified consultant. He introduced the theory

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[4]R. M. Barnes, Motion and Time Study, 3d Ed. (New York: John Wiley & Sons, 1949) pp. 347 & 352.

[5]W. B. Wisecarver, Setting the Worker Normals for Time Study Purposes (Factory Management and Maintenance, Vol. 104, No. 10, October, 1946) p. 122-6.

that any group of intelligent people has, collectively, a good concept of "normal" on any simple operation; also, that it is not too difficult to correct for the few exceptions to the group average.

The first step was the establishment of a uniform "leveling" factor based on a normal of 100 per cent with 5 per cent increments for evaluating operative differences.

The second step was to bring together a representative group for the purpose of rating performances of a series of jobs, using the uniform leveling factor. This group was not limited to time-study and methods engineers but included the factory superintendent, foremen, set-up men, group leaders and union stewards. During the initial stages only those persons well acquainted with the jobs being rated were called on to rate the performances.

Twelve or fifteen different operations were selected and the operators were instructed to perform at a tempo of their own choosing but to maintain that level as nearly as possible throughout the rating session. None of the raters were to divulge their ratings until the session was completed. An experienced time-study engineer recorded the elemental times for the purpose of checking results of the individual observers. The individual ratings were purely the raters conception of what he judged the operator was doing in terms of effective performance expressed in per cent of normal, 100 per cent. These ratings were averaged and this average rating was assumed to be the probable correct rating for the operator being observed. When the individual ratings were plotted against this average it was revealed that 75 to 80 per cent were within 5 per cent, plus or minus. Only 2 or 3 per cent deviated from the average by more than 10 per cent.

After these preliminary steps were completed, approximately, forty persons were selected to study a variety of operations to learn how closely they could rate types of work on which they had had no actual experience. Jobs chosen included assembly as well as machine work.

From study of the results of this larger group, it was concluded that any group of intelligent people could be taught to judge an operator's performance, especially when near normal. It was observed that, when an operator was performing at normal or within 20 per cent, plus or minus, of normal, these people were nearly always in agreement as to the proper rating. However, when the tempo exceeded 120 per cent or was less than 80 per cent, the judgments began to waiver and became inconsistent. Here, as has been observed elsewhere, the raters tended to under rate high-speed performances and to over rate the slow-speed.

Both of these examples are cited to show that inexperienced as well as experienced raters vary materially in ability to rate performances in a uniform manner. From the rating standpoint, alone, there is possibility of a minimum error of 10 per cent. Such differences are, of course, reflected in the overall performance evaluation of individual worker performance.

Everyone is familiar with the fact that no two individuals are exactly alike and that inherent differences may be expected to prevail in their work performances. According to Harrell[6] industrial psycholo-

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[6]T. W. Harrell, Industrial Psychology (New York: Rhinehart and Company, 1949) p. 164.

logists oppose the practices of those motion-time authorities who advocate determining the one-best way to perform each job and training the worker so that he will follow that exact pattern. The counter-proposal is that each employee should be taught a good way to perform a given job or task and then be allowed to vary from that pattern as may be required to compensate for individual differences. Motion economy should not, therefore, prevent employees from using some motions that may appear inefficient but which contribute to the rhythm of the work effort.

Harrell has also stated that the matter of individual differences comprised the first study undertaken by the industrial psychologists and that it has received more attention than any other problem. The amount of detailed data now available on industrial employees is not of great magnitude.[7]

The rhythm factor and use of both hands, simultaneously, are of considerable importance when viewed from the productivity standpoint. This was emphasized by results of a test in which individuals, using both hands, were required to push slider blocks back and forth along bars. The ends of the bars nearest the body were pivotted and the outward ends were free to rotate to any desired angle within a 90 degree arc. The best "average" speeds were attained when there was a 60 degree angle between the plane of the body and the direction of motion. The fastest individual times, however, were recorded for those individuals whose hands were moving in opposite directions along the bars positioned

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[7] Ibid, p. 53.

at an angle of 0 degrees with the plane of the body[8].

Figure 1 page 92 shows the extent to which an individual's performance times may vary with respect to that individual's average time for a series of repetitive operations. This data reveals that the individual deviation ranges are of less magnitude for the slower free-choice tempo than for the fastest pace. This substantiates the findings of Roethlesberger and Dickson[9] who made a somewhat different approach. They observed that individual deviation differences, morning vs. afternoon, were of greater magnitude for the fastest workers and that the slow-pace worker curves exhibited much less variation.

By contrast, comparison of Figures 4, 6, 8, and 10 shows that dispersion of individual averages, with respect to the mean for the group, is least for the fastest tempo and increases as the pace slows. The faster paces are of motivational order.

Another factor affecting the performance rate is that of relating concentration and movement. So long as the effort can be of rhythmical nature and of such simplicity as to require very little mental effort the performance times are indicative of relatively high efficiency. Any variation of method that introduces minimum application of mental may cause a noticeable increase in the overall performance time.[10]

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[8] Loc. cit., p. 164.

[9] F. J. Roethlesberger and W. J. Dickson, <u>Management and the Worker</u> (Cambridge, Mass.: Harvard University Press 1949) p. 436.

[10] Infra, Table XXI.

Complete analysis of operational motions can, perhaps, be most revealing of individual differences for any given job. A series of motions which can be rhythmically accomplished are, reputedly, conducive to fastest performance times.[11] Motions which do not blend or merge, one into the other, produce longest performance times.

As a result of micro-motion study of a number of operators performing the same standardized operation, for detection of the effect of skill and effort on motion times, Stegmerten and associates[12] reported that no two operators followed identical motion patterns and that differences were of far greater magnitude than would be apparent to the casual observer. It was also revealed that individual operatives varied their methods on successive cycles. The differences in individual outputs were attributed to method differences; that is, difference in the number of motions used. The most productive operator, rated at 123 per cent efficient, used 21.8 basic elements per cycle compared with 41.7 elements for the least productive, rated 86 per cent efficient. This gave a ratio of 192:100 for the motions used.

Authorities who appear to have made the greatest contributions to the development of motion analysis are Barnes, Holmes, and Maynard, Stegmerten and Schwab. These contributors have classified the various types of motion, normally encountered in industrial operations, and have prepared tables of standard times for these motions.

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[11] R. M. Barnes, loc. cit., p. 227.

[12] Maynard, Stegmerten and Schwab, Methods and Time Measurement (New York: McGraw-Hill Book Co., Inc., 1948) p. 278.

Studies of Taylor's[13] projects for the handling of pig iron and for the shoveling of steel-making materials showed, to the satisfaction of many, that method and speed of motions were the limiting factors on the productivity range during the work cycle.

Segur[14], another proponent of motion-time methods, has propounded as a natural physical law, the theory that

> "within practical limits, the times required by all expert workers to perform true fundamental motions is a constant."

He has defined "practical limits" as maximum variation of 20 per cent and, again, as the limits that usually surround the performance of work and motions taking longer than .0001 minute to complete. The terms "expert workers" and "fundamental motions" are not as clearly defined.

In commenting on the method of comparing specific motion times with standards, Presgrave[15] indicated that the method, though idealistic, held considerable promise insofar as simple motions were concerned. Because of the paucity of conclusive data and the lack of standards tables, for better evaluation, he relegated the motion-time method to the academic level. His lack of knowledge of definitions for proper application of Segur's Law of Motion Time caused him to view that method questioningly.

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[13] F. W. Taylor, Scientific Management: The Principles of Scientific Management (New York: Harper Brothers, 1947) pp. 43 and 65.

[14] A. B. Segur, The Story of Motion Time Analysis, (Oak Park, Ill.: A. B. Segur and Co.) p. 7.

[15] Presgrave, op. cit., p. 57.

Presgrave[16] also questioned the validity of using standard motion times, for universal application, because of the variations inherent in materials over which the operator has no control; namely, resistance of materials to shaping and fabrication.

On the other hand, Stegmerten and associates[17] maintained that there was no necessity for judging the performance level of the operator in the application of their system. For application, it is only necessary to determine the exact motions required for the given performance and to assign predetermined time standards to each limiting motion. The "limiting motion" is defined as that one of two or more simultaneous or concurrent motions requiring the longest element of time for performance. Summation of all of the separate limiting motion times represents the production standard for the job. By this method the judgment factor is transferred to the evaluation of the correctness of motions used in job performance.

One of the basic principles of scientific management is the removal of all barriers to the continuous performance of production workers. For fulfillment, management must develop efficient work stations, establish continuous flow of materials and production tools to the operators, provide an adequate program of development and maintenance of tools, machinery and equipment, and provide the operators with written instructions and supervision to eliminate need for excessive mental effort.

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[16] Loc. cit.

[17] Maynard, Stegmerten and Schwab, op. cit., p. v.

Gilbreth[18] pioneered the application of the principles of scientific management in the construction field. The practice of training the helper, who supplied the bricks to the mason, to position the bricks selectively in the "pack" relieved the mason of the task of face selection. Correctly tempered mortar made possible the bedding of the bricks to proper depth with hand pressure rather than by trowel tap. Proper elevation and location of brick "packs" and mortar boards, with respect to the mason's station, minimized the turning and stooping. These features, plus minute study of the motions actually required for proper bricklaying, made possible the reduction of movements from 18 per brick to 5 and for one type to a low of two. By such techniques the average production, for standard conditions, was increased from 120 per hour to 350 per hour. One of the more important phases of the Gilbreth method was the teaching of mechanics the simultaneous use of both hands instead of successively.

The success of any revolutionary technique can be assured only through training. H. L. Gantt[19], a noted pioneer industrial engineer, was the first to campaign vigorously for management sponsored programs for worker training. Even though he well publicized his successes in this function of management, a period of ten years were to elapse before the practice received general industrial recognition.

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[18] F. B. Gilbreth, Bricklaying System (New York: Myron C. Clark Pub. Co.)

[19] L. P. Alford, Henry Laurence Gantt: Leader of Industry (New York: The American Society of Mechanical Engineers, 1934) pp. 138-48.

Tiffin[20] has stated that tests and studies prove conclusively that training assures improved production levels. It was further revealed that training can also accentuate rather than lessen the effects of individual differences, from the productive range standpoint. He also advocated that the high-level producer will maintain that position consistently and that the low-level producer will remain in a relatively lower position, even after comprehensive training. It must be concluded that training cannot be considered an instrument for equalization of the productive abilities of all individuals. Following a series of tests of manual ability of a group of individuals who had just completed three months of intensive training, Tiffin found that improvement was more apparent for those of the group who tested low, initially, than for those who showed high-level potentials, originally. Additional conclusions were that, for simple tasks, there will be a decrease in the effects of individual differences whereas, for work of more complicated nature, the differences may be accentuated and, for tasks of an intermediate nature, the differences may be unaffected.

As a result of his findings another psychologist[21] concluded that organized training and practice definitely raises the proficiency at which a capacity can be made to function. Accumulated evidence was not convincing that training could destroy individual differences or

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[20] Joseph Tiffin, Industrial Psychology, (New York: Prentice-Hall, Inc., 1947) pp. 18-20.

[21] M. S. Viteles, Industrial Psychology (New York: W. W. Merton and Co., Inc., 1932) p. 108.

materially change the relative rank of an individual compared with these around him.

In his chapter on training methods, Viteles[22] cited certain ones of major differences that exist between the philosophies of industrial psychology and method engineering. These pertain chiefly to the psychologists' opposition to the "one-best-way" theory advocated by many of the latter profession. In support of this contention, he cited observations of E. Farmer, psychologist, which were, in part, as follows:

> 1. All time and motion study must be undertaken solely in the interests of lessened fatigue and never in the interests of increased production. ...
>
> 2. The underlying principle of motion study is rhythm and net speed. The best set of movements is the easiest set and not necessarily the quickest set.
>
> 3. ... All effort of the investigation should be concentrated on lessening fatigue and increasing the ease with which the operation can be performed; other things being equal the operatives will set their own standards. ...
>
> 4. Time and motion is only part of a whole region of study affecting the human element in industry and can only be carried out in conjunction with the study of other equally fundamental problems.

Lytle[23] has stated that the pioneer industrial engineers learned

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[22] Ibid, pp. 436-37.

[23] Charles W. Lytle, Job Evaluation Methods (New York: The Ronald Press, 1946) p. 219.

early that skilled operators must be paid 120 per cent the prevailing rates to insure production of 100 per cent high task. Taylor[24] advocated that incentive payments ranging from 30 per cent to 100 per cent, for varied occupations, were essential for the constant attainment of maximum output.

Present day incentive programs include far greater problems than the wage payment consideration. Programs inclusive of worker welfare and retirement, promotions and pay increases through merit rating, and other unique devices are commonly used to improve employee morale and to encourage maximum continuous output.

Management's position in the matter is not too enviable. The extent to which it is economical to go beyond the more practical rating techniques into the realm of the less well understood techniques of the industrial psychologists is a problem of great magnitude. Few firms appear to be willing or can afford to expand funds necessary for solving the overall problem. Few individuals possess the zeal of a Taylor and are willing to expend personal fortunes in such researches.

The foregoing comments and criticisms point up many of the inconsistencies and inequalities that prevail in connection with the problem of correctly evaluating the actual performance rates of individual workers. Much of the weakness is attributable to the failure of authorities, in the field, to find common ground for the settlement of some of the major differences within the various systems. Continuing

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[24] F. W. Taylor, op. cit., p. 39.

and growing interest is evidenced by the increasing amounts of material published annually. Entry of a greater number of industrial psychologists into the field of research on matters related to productive effort has spurred greater interest. No doubt much proven data remains, as yet, unpublished and it is expected much of it will contribute greatly to further enlighten the problem.

IV

INDIVIDUAL PERFORMANCE DIFFERENCES (PERSONAL)

Individuals engaged in the performance of work are assailed to varying degrees by limiting factors of a nonoperational nature. The effects of these factors are definitely reflected in the productivity of the individual and the effect of some of them have not as yet been completely interpreted.

Sylvester[1] has branded methods practiced by time study engineers, in the evaluation of time standards, as confessions of weakness because of what he termed temporary nature. In other words, the use of leveling and rating factors were viewed as evidence of the lack of faith in the method used. He asserted that the purely scientific concept requires a more intimate knowledge than the broad general statement that time study deals with the mechanical and the human aspects of the work. Full knowledge of the nature of the work, an outline of its boundaries and a description of its varieties are stressed as necessities as opposed to the more common temporary expendiencies.

This authority has gone so far as to compare the dynamic efficiency of the human organism to that of various power producing devices. The analogy was expressed as effiency relationship of the antimate capacity to that of the mechanical device as: motorcycle, 1.25:1; truck and bus engines, 1.14:1; diesel bus and truck engines, .86:1; and

[1] L. A. Sylvester, The Handbook of Advanced Time-Motion Study (New York: Funk and Wagnalls, 1950) p. 4.

stationary diesel engines, .83:1. On the acceptance of such a hypothesis, it becomes immediately apparent that the low-level performances of many individuals represents a loss of considerable production.

Unlike the performance characteristic of a mechanical power plant, the influence of fatigue appears early in the performance of the human being and continues to build up noticeably if the work effort is prolonged unless rest or recuperation periods are authorized. The length and spacing of rest periods were considered of great importance in the high-level production schedules directed by Taylor. It is exceedingly difficult to segregate the fatigue decrement from other effects such as boredom or psychological, phsiological and sociological influences, for separate analysis.

Lack of knowledge of the true influence of recuperative routines on physical and mental capacities has given rise to many differing opinions. Programs for concert pianist recitals usually include one or more light pieces between those requiring greater effort, to compensate for the accelerated output. Operative changes in motion patterns of successive cycles of a repetitive work series are considered attempts by the operators to accomplish the same relief objective. Responsibility for the proper evaluation and inclusion of all such effects on individual performances, in all likelihood, can never be successfully imposed upon the motion-time engineer at the application level.

At the behest of Taylor, Barth[2] deduced by complex mathematics

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[2]F. W. Taylor, Shop Management (New York: Harper and Bros., 1947) p. 57

that, for the continuous handling of 92-pound pigs of iron, the worker could be laden but 43 per cent of the work period; that is, for ten hours. Higher percentage load times were evolved for the manual movement of items of lesser weight. Such mathematical treatment apparently has not been done extensively in recent year.

Because of the confusion and uncertainity surrounding the true identity and effects of the elements inducing fatigue during periods of continuous exertion, certain of the authorities in the industrial field have recommended that the concept of fatigue be entirely eliminated from the scientific discussions of industrial work.

Cohen's[3] system for the establishment of correct performance standards excludes the addition of a separate fatigue factor. His technique places a high premium on the judgment capacity of the time study observer. During the timing process the observer is expected to superimpose upon the performance being observed a mental picturization of the motion speeds at which the operator could perform continuously without dimunition of productive effort. Time values are adjusted to conform to the visualized standard performance.

Cohen[4] reported that Kirkhoven, a Dutch authority, has sought to eliminate the need for including a fatigue factor in his calculations through the use of measured single-cycle times and continuous performance curves, in combination.

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[3]Abraham Cohen, Time Study and Common Sense (London: McDonald and Evans, 1947) p. 57.

[4]Loc. cit. p. 19.

The influence of such factors as the boredom created by monotous repetition, the psychological, the physiological, the sociological, "soldering" and the variables of the human equation are all less clearly understood than is that of the diminishing influence of continuous effort on the individual reservoir of energy. Techniques for the measurement of such factors are rather uncommon.

From a practical standpoint, Viteles has indorsed the production curve as the most satisfactory determinant of the effect of methods and conditions upon the individual capacity for work. The characteristic curve is shown in Figure 2, page 93 . In principle it is assumed that the forces of training and fatigue are antagonistic in effect. When the effect of training is in the predominating position the output curve reflects a rising characteristic. However, as the effects of fatigue and related factors equal that of the training influence, the curve levels off, and as the adverse factors increase further the curve shows a decreasing characteristic. In other words, the curve pictures the collective effect of all the variables on the range of human productivity.

Morrow[5] has listed the causes of fatigue as follows:

1. Unsatisfactory emotional adjustment.
2. Bodily deficiencies.
3. Unsuitable surroundings.

Such reasoning would seem to eliminate from consideration any relationship between the decreasing worker output required for continuous

[5]Robert L. Morrow, Time Study and Motion Economy, (New York: The Ronald Press Co., 1946) p. 142

performance. However, for practical application, this authority has tabulated certain percentage allowances for the fatigue element which are useful data for the typical computation of standard times for various types of work.

Tabulations compiled from daylong performance data make it relatively easy to determine approximate fatigue factors for subsequent use.

V

EXPERIMENTATION AND INVESTIGATION

Discussions in the foregoing chapters have created need for first-hand knowledge of performance relationships. Accordingly, a series of card-dealing tests were conducted using a group of college engineering students as subjects.

Card dealing was used to simulate work because of the simplicity of the operation and for the ease with which novices can acquire sufficient skill for acceptable performances. Four thirteen-card hands constituted a single cycle.

Control measures by which variables were held to a minimum included four seven-inch square boxes with one-inch high sides, arranged as shown in Figure 18, page 111, to receive the cards dealt, plus the requirement that the knuckles of hand holding the deck be held at rest on the table top.

The remaining uncontrolled variables were adjudged to be individual action times of positioning and distributing the cards and the distance that the deal hand traveled in disposing each card into its approximate box.

The seat height throughout the series of tests placed the table top at appropriately waist level to give elbow elevations slightly above the horizontal.

Cycle times were measured by Marstochron and splithand decimal-minute stopwatch. Accuracy of .001 minutes is characteristic of each of these devices.

It was proposed to study, in a modified manner, under two hypotheses propounded by Hull and Wechsler, cited by Presgrave[1] as follows:

1. Human capacities divide into several groups in each of which there is a well defined uniform range from the lowest to the highest degree.

2. Throughout each of the ranges distribution follows a distinct and universal pattern which can be reduced to a working formula.

Investigative effort was directed toward the analysis of the question:

"WHAT ARE THE CHARACTERISTICS OF THE PERFORMANCE RANGE?"

under the following sub-headings:

1. What are the performance ranges at various paces?

2. Can definite levels of performance be identified?

3. How many definite levels of performance can be identified?

4. What is the relationship of these levels to each other?

5. What are the characteristics of each level?

6. What is the relationship of the individual to each level?

7. What is the influence of method?

8. Can it be established that the range is continuous or do definite increments exist?

9. Predictability of the results.

For purposes of statistical simplification the averages of the five- and three-cycle deal times for the respective subjects were

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[1]Ralph Presgrave, The Dynamics of Time Study, (New York: McGraw-Hill Book Co., Inc., 1945) p. 88.

taken as starting points for the mathematical treatment of the results.

As is customary, according to time study practices, the basic assumption was made that the individual differences have the characteristic of normal distribution and can be so represented by the bell-shaped distribution curve.

In the majority of cases the subjects dealt a series of five consecutive cycles; however, some were limited to three cycles by shortage of available time. The recorded times cover deal only and do not include the pick-up times between deals.

In order that the performance characteristics could be better visualized for the overall operational range for the group of subjects it was decided to stipulate several pace rates from the slowest to the fastest. The paces indicated below are those of which, it was reasonable to assume, the subjects had sound concept. Accordingly, deal tempos for the investigation included:

1. Fastest pace
2. Incentive pace
3. Normal pace
4. Free choice pace
5. Slowest pace

All group participation for each deal pace was completed before any individual performed at another pace. The raw data was accumulated over a period of approximately eight weeks.

Instructions were issued the performers as follows:

1. Under conditions[2] stipulated, deal five cycles as rapidly as possible in straight clockwise rotational order but, with restraint necessary to insure deposit of cards in appropriate boxes. Consistent speeds are desired.

2. Under conditions stipulated, deal five cycles at what is to be that maximum or incentive pace which could be maintained, without excessive fatigue, for eight hours daily, indefinitely. Deal in straight rotational clockwise order exercising the restraint necessary to insure placement of the cards in the appropriate boxes. Maintain speed consistency.

3. Under conditions stipulated, deal five cycles at that pace defined as "normal" with respect to the incentive pace. That is, for the incentive pace, perform at the 100 per cent level. Exercise special care to place the cards in the boxes. Proceed in straight rotational order in clockwise direction. Maintain speed consistency as nearly as possible.

4. Under conditions stipulated, deal five cycles at that pace one would choose if there were no incentive to perform more rapidly. Exercise effort to get the cards into appropriate boxes and proceed in straight rotational clockwise order.

5. Under conditions stipulated, deal five cycles at the slowest continuous pace possible to maintain without imposing self-restraint. Proceed in rotational clockwise order and get the cards into appropriate boxes.

Additional tests included performances of:

1. Single individuals dealing for extended periods at certain prescribed paces.

2. A group instructed to deal straight rotational order and on the diagonals, alternately, for a total of ten cycles at the fastest attainable pace.

3. Small groups dealing in order:

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[2] Supra, p. 31.

a. Three fast-pace cycles followed by
b. Three cycles at a <u>slower</u> pace

4. A small group operating under no instructions other than to deal three cycles.

The recorded times data and computations thereon follow.

Statistical Analysis of the Fastest Pace Times
for Straight Rotational Dealing

TABLE I

COMPUTATION OF AVERAGE AND STANDARD DEVIATION OF FREQUENCY DISTRIBUTION FOR THE FASTEST PACE

No.	Class	No. of Freq.(f)	Deviation from Assumed Mean (d)	f(d')	f(d')^2
1	.270-.299	2	-2	-4	8
2	.300-.329	14	-1	-14	14
3	.330-.359	22	0	0	0
4	.360-.389	18	1	18	18
5	.390-.419	14	2	28	56
6	.420-.449	2	3	6	18
7	.450-.479	2	4	8	32
		74		42	146

Arithmetic Mean or Average for Sample.

$$\overline{X} = .3445 + \frac{(42)}{(74)}.03 = .3445 + .0171 = .\underline{362} \text{ minutes}$$

Median of the Sample. Mid point of all frequencies: N/2 = 37 frequencies. Since but 16 frequencies occur in the first two classes interpolation into the 3rd class gives:

$$M = .3295 + \frac{(37 - 16).03}{22} = .3295 + .0286 = .\underline{358} \text{ minutes}$$

Modal Average of the Sample.

$$M_o = .3295 + \left[\frac{22-14}{(22-14)+(22-18)}\right].03 = .3295 + .0200 = .\underline{350} \text{ min.}$$

$$\sigma = .03\sqrt{\frac{146}{74} - (42)^2} = .03\sqrt{1.652} = .\underline{[illegible]} \text{ minutes}$$

Quartile Distribution for the Sample. First point: Q 1 at N/4 = 74/4 = 18.5 frequencies above lowest. Since but 16 frequencies occur in the first 2 classes interpolation gives

$$Q_1 = .3295 + \frac{(18.5 - 16)}{22}.03 = .3295 + .034 = \underline{.333} \text{ minute}$$

Mid point: Q_2 = Median = $\underline{.358}$ minute

Third point: Q_3 at $N/4 = 74/4 = 18.5$ frequencies from the highest limit. Since but 18 frequencies occur in the three classes interpolation into the 4th class gives:

$$Q_3 = .3895 + \frac{(18.5 - 18)}{18}.03 = .3895 + .0008 = \underline{.389} \text{ minute}$$

<u>Skewness of the Sample Curve</u>.

$$Sk = \frac{3(.362 - .358)}{.386} = +.01 \text{ skewed to the right, slightly}$$

<u>Standard Deviation of the Population Estimated from Sample</u>

$$\sigma = .03\sqrt{\frac{146}{73} - \frac{(42)^2}{74 \text{x} 73}} = .03\sqrt{1.674} = \underline{.0388} \text{ minute}$$

<u>Standard Error of the Mean</u>

$$\sigma_{\bar{x}} = .0388/\sqrt{74} = .0388/8.6 = .00452$$

<u>Dependability</u>. For $\sigma_{\bar{x}} = .0045$, two times out of three, the sample means will fall within a range of $\pm$ .0045 of the population mean. By the 5 per cent fidicual limit concept, it can be safely assumed that the confidence interval is .353 to .371 minutes. That is, in 95 times out of the 100 the mean of any sample will neither equal nor exceed the upper limit (.371) nor will it equal or be less than the lower limit (.353).

It is further stated with confidence that, for practical purposes, 99.73 per cent of the population lies within the interval

$\bar{X} \pm 3\bar{\sigma}$ or that the population limits are:

$$\bar{X} + 3\bar{\sigma} = .362 + 3 \times .0388 = \underline{.478} \text{ minute}$$
$$\bar{X} - 3\bar{\sigma} = .362 - 3 \times .0388 = \underline{.246} \text{ minute}$$

Accordingly, the range of effort for the stipulated conditions at the fastest pace is .478/.246 or 1.95:1

Computation of Ordinate Values for Normal Curve.

Maximum ordinate: $Y_o = \dfrac{.03 \times 74}{.0386 \times 2.5066} = \underline{22.9}$ frequencies

TABLE II

ORDINATE VALUES FOR FASTEST PACE DISTRIBUTION CURVE

Ordinate Time Values x_1	x_2	x/σ	Appendix D[4] Factor	Ordinate Value (Frequency)
0	0			22.9
.332	.392	.778	.68	15.6
.302	.422	1.556	.298	6.8
.272	.482	2.334	.066	1.5
.242	.482	3.112	.008	.2

[4] F. E. Croxton and D. J. Cowden, Applied General Statistics (New York: Prentice-Hall, Inc.) 1947 p. 872.

Statistical Analysis of the Incentive Pace
Times for Straight Rotational Dealing

TABLE III

COMPUTATION OF AVERAGE AND STANDARD DEVIATION OF FREQUENCY
DISTRIBUTION FOR THE INCENTIVE PACE

No.	Class	No. of Freq.(f)	Deviation from Assumed Mean	f(d')	f(d')^2
1	.330-.359	10	-2	-20	40
2	.360-.389	13	-1	-13	13
3	.390-.418	22	0	0	0
4	.420-.449	16	1	16	16
5	.450-.479	7	2	14	28
6	.480-.509	5	3	15	45
7	.510-.539	1	4	4	16
		74		16	158

Arithmetic Mean or Average of the Sample.

$$\overline{X} = .4045 + \frac{(16)}{(74)}.03 = .4045 + .0065 = .\underline{411} \text{ minute}$$

Median of the Sample. Mid point of all frequencies: N/2 = 74/2 = 37 frequencies. Since there are but 23 frequencies in the first two classes interpolation into the 3rd class gives:

$$M = .3895 + \frac{(37 - 23).03}{22} = .3895 + .0191 = .\underline{409} \text{ minute}$$

Modal Average of the Sample.

$$M_o = .3895 + \left[\frac{(22 - 13)\ .03}{(22-13)-(22-16)}\right] = .3895 + .018 = .\underline{408} \text{ min.}$$

Average Deviation of the Sample.

$$\sigma = .03 \sqrt{\frac{158}{74} - \frac{(16)^2}{(74)}} = .03 \sqrt{2.087} = .\underline{0434} \text{ minute}$$

Quartile Distribution of the Sample. First point: Q_1 at N/4 =

$74/4 = 18.5$ frequencies in 1st or lowest quartile. Since but 10 frequencies occur in the first class interpolation into the 2nd class gives:

$$Q1 = .3595 + \frac{(18.5 - 10)}{13}\ .03 = .3595 = .0196 = \underline{.379} \text{ minute}$$

Mid point: Q_2 = Median = $\underline{.409}$ minute

Third point: Q_3 at $3N/4 = 3 \times 74/4 = 55.5$ frequencies which number is 18.5 frequencies below the total number. Since but 13 frequencies occur in the last three classes, interpolation into the 4th class gives:

$$Q_3 = .4495 - \frac{(18.5 - 13)}{16}.03 = .4495 - .0103 = \underline{.439} \text{ minute}$$

<u>Skewness of the Sample Curve.</u>

$$Sk = \frac{3(.411 - .409)}{.0434} = \underline{+.046} \text{ slightly skewed to the right}$$

<u>Standard Deviation of the Population Estimated from Sample.</u>

$$\sigma = .03 \sqrt{\frac{158}{73} - \frac{(16)^2}{73 \times 74}} = .03 \sqrt{2.118} = \underline{.0437} \text{ minute}$$

<u>Standard Error of the Mean.</u>

$$\sigma_{\bar{x}} = .0437/\sqrt{74} = .0437/8.6 = \underline{.00508} \text{ minute}$$

For $\sigma_{\bar{x}} = .00508$, two times out of three, the means of all samples of the population will fall within the range of $\pm$ .00508 minutes of the population mean. By the 5 per cent fiducial concept it can be safely assumed that the confidence interval is from .401 to .421. That is, in 95 times out of 100 the means of the samples will neither equal nor exceed the upper limit (.421) nor will they equal or be less than the lower limit (.401).

It can be further stated with confidence that, for practical purposes, 99.73 per cent of the population lies within the interval

$\bar{X} \pm 3\bar{\sigma}$, or that the extreme limits of the population are:

$$\bar{X} + 3\bar{\sigma} = .441 + 3 \times .0437 = \underline{.542} \text{ minute}$$
$$\bar{X} - 3\bar{\sigma} = .441 - 3 \times .0437 = \underline{.280} \text{ minute}$$

Accordingly, the range of effort for stipulated conditions at the incentive operational pace is the ratio of .542/ .280, or 1.95:1.

Computation of Ordinate Values for the Normal Curve

Maximum ordinate: $Y_o = \dfrac{.03 \times 74}{.0434 \times 2.5066} = \underline{20.4}$ frequencies

TABLE IV

ORDINATE VALUES FOR THE INCENTIVE PACE DISTRIBUTION CURVE

Ordinate Time Values x_1	x_2	x/σ	Appendix D[5] Factor	Ordinate Value (Frequency)
0	0			20.4
.381	.441	.687	.842	17.1
.351	.471	1.372	.415	8.4
.321	.501	2.060	.120	2.4
.291	.531	2.750	.023	.5
.261	.581	3.430	.003	.1

[5] Loc. cit.

Statistical Analysis of Normal Pace Deal Times
For Straight Rotational Dealing

TABLE V

COMPUTATION OF AVERAGE AND STANDARD DEVIATION OF FREQUENCY DISTRIBUTION FOR THE NORMAL PACE

No.	Class	No. of Freq.(f)	Deviation from Assumed Mean(d')	f(d')	$f(d')^2$
1	.360-.389	4	-3	-12	36
2	.390-.419	6	-2	-12	24
3	.420-.449	14	-1	-14	14
4	.450-.479	23	0	0	0
5	.480-.509	19	1	19	19
6	.510-.539	4	2	8	16
7	.540-.569	4	3	12	36
		74		1	145

Arithmetic Average or Mean of Sample

$$\bar{X} = .4645 + \frac{(1)}{(74)}\, .03 = .4645 + .0004 = \underline{.465} \text{ minute}$$

Median of Sample. Midpoint of all frequencies: N/2 = 74/2 = 37 frequencies. Since but 24 frequencies occur in the first 3 classes, interpolation into the 4th class gives

$$M = .4495 + \frac{(37-24)}{23}.03 = .4495 + .0174 = \underline{.466} \text{ minute}$$

Mode of the Sample.

$$M_o = .4495 + \left[\frac{23 - 14}{(23-14) + (23-19)}\right] .03 = .4495 + .0208 = \underline{.470} \text{ min.}$$

Average Deviation of the Sample.

$$\sigma = .03 \sqrt{\frac{145}{74} - \left(\frac{1}{74}\right)^2} = .03 \sqrt{1.96 - .0002} = \underline{.042} \text{ minute}$$

Quartile Distribution Limits for Sample. First point: Q_1 at $N/4$ = 18.5 frequencies above lowest. Since but 10 frequencies occur in the first two classes, interpolation into the 3rd class gives:

$$Q_1 = .4195 + \frac{(18.5 - 10)}{14}.03 = .4195 + .0182 = .\underline{438} \text{ minute}$$

Midpoint: Q_2 = median = .466 minute

Third point: $Q_3 = N/4$ = 18.5 frequencies below highest

Since but 8 frequencies occur in the last two classes, interpolation into the 5th class gives:

$$Q_3 = .5095 + \frac{(18.5 - 8)}{19}.03 = .5095 - .0167 = .\underline{493} \text{ minute}$$

Skewness of the Sample Curve

$$Sk = \frac{3(.456 - .466)}{.042} = -.0715 \text{ skewed to the left; abnormal}$$

Standard Deviation of the Population Estimated from Sample.

$$\bar{\sigma} = .03 \sqrt{\frac{145}{73} - \frac{1^2}{73 \times 74}} = .03 \sqrt{1.987} = .\underline{0423} \text{ minute}$$

Standard Error Of Mean.

$$\sigma_{\bar{x}} = .0423/\sqrt{74} = .0423/8.6 = .00504$$

Dependability. For a $\sigma_{\bar{x}} = .00504$, in two cases out of three, all sample means will fall within a range of $\pm$ .00504 minutes of the population mean. By the 5% fiducial limit concept it can be assumed that the confidence interval is .445 - .475. That is, in 95 times out of 100, the means of the samples will neither equal nor exceed the upper limit (.475) nor will it equal or be less than the lower limit (.455).

For practical purposes it can also be stated with confidence that 99.73 per cent of the population lies within the $\bar{X} \pm 3\sigma$ interval, or that the extreme limits are:

$$\bar{X} + 3\sigma = .465 + 3x.0423 = \underline{.592} \text{ minute}$$
$$\bar{X} - 3\sigma = .465 - 3x.0423 = \underline{.338} \text{ minute}$$

Accordingly, it can be stated that the range of effort at the normal pace under stipulated condition is the ratio of the highest limit to the lowest limit, .592/.338 or 1.75:1.

Computation of Ordinate Values for the Normal Curve.

$$\text{Maximum ordinate : } Y_o = \frac{.03 \times 74}{.042 \times 2.5066} = \underline{21.1} \text{ frequencies}$$

TABLE VI

ORDINATE VALUES FOR THE NORMAL PACE DISTRIBUTION CURVE

Ordinate Time Values x_1	x_2	x/σ	Appendix D[6] Factor	Ordinate Value (Frequency)
0	0			21.1
.435	.495	.715	.7744	16.34
.405	.525	1.43	.3597	7.58
.375	.555	2.14	.1013	2.14
.345	.585	2.86	.0167	.35
.315	.615	3.58	.0035	.07

[6] Loc. cit.

Statistical Analysis of Free Choice Pace Deal Times for Straight Rotational Dealing

TABLE VII

COMPUTATION OF AVERAGE AND STANDARD DEVIATION OF FREQUENCY DISTRIBUTION FOR THE FREE CHOICE PACE

No.	Class	No. of Freq.(f)	Deviation from Assumed Mean(d')	f(d')	f(d')^2
1	.330-.359	2	-4	-8	32
2	.360-.389	4	-3	-12	36
3	.390-.419	5	-2	-10	20
4	.420-.449	16	-1	-16	16
5	.450-.479	16	0	0	0
6	.480-.509	10	1	10	10
7	.510-.539	9	2	18	36
8	.540-.569	5	3	15	45
9	.570-.599	1	4	4	16
10	.600-.629	2	5	10	50
11	.630-.659	2	6	12	72
12	.660-.689	2	7	14	98
		74		37	413

Arithmetic Average or Mean of the Sample.

$$\bar{X} = .4645 + \frac{(37)}{(74)}.03 = .4645 + .0150 = \underline{.480} \text{ minute}$$

Median of the Sample. Mid-point of all frequencies: N/2 = 74/2 = 37 frequencies. Since but 27 frequencies occur in the first 4 classes, interpolation into the 5th class gives:

$$M = .4495 + \frac{(37 - 27).03}{16} = .4495 + .0188 = \underline{.470} \text{ minute}$$

$$M_o = .4495 + \left[\frac{(16-16).03}{(16-16) + (16-10)}\right] = .4495 + 0 = \underline{.450} \text{ minute}$$

Average Deviation of the Sample.

$$\sigma = .03 \sqrt{\frac{413}{74} - \frac{(37)^2}{(74)}} = .03 \sqrt{5.33} = \underline{.0694} \text{ minute}$$

Quartile Distribution Limits for Sample. First point: Q_1 at $N/4 = 74/4 = 18.5$ frequencies below. Since but 11 frequencies occur in the first three classes, interpolation into the 4th class gives:

$$Q_1 = .4195 + \frac{(18.5 - 11)}{16}.03 = .4195 + .0141 = \underline{.433} \text{ minute}$$

Mid point: Q_2 = Median Value = $.\underline{470}$ minute

Third Point: Q_3 at $N/4 = 18.5$ frequencies above high point. Since but 12 frequencies occur in the last 4 classes, interpolation into the class gives:

$$Q_3 = .5395 - \frac{(18.5 - 12)}{9}.03 = .5359 - .0217 = .\underline{518} \text{ minute}$$

Skewness of the Sample Curve.

$$Sk = \frac{3(\ .48 - .47)}{.0694} = +.\underline{433} \text{ skewed to the right}$$

Standard Deviation of the Population Estimated from Sample

$$\bar{\sigma} = .03\sqrt{\frac{413}{73} - \frac{(37)^2}{73 \times 74}} = .03\ \sqrt{5.40} = \underline{.0696} \text{ minute}$$

Standard Error of the Mean.

$$\sigma_{\bar{X}} = .0696/\sqrt{74} = .0696/8.6 = .00811$$

Dependability. For a $\sigma_{\bar{X}} = .00811$, in two cases out of three, all sample means will fall within a range of $\pm$ .00811 minutes of the population mean. By the fiducial 5% limit concept, it can be assumed that the confidence interval is between .464 and .496. That is, in 95 times of 100 the means of the samples will neither equal nor exceed the upper limit (.496) nor will it equal or be less than the lower limit (.464).

It is further stated with confidence that, for practical purposes, 99.73 per cent of the population lies within the interval $X \pm 3\sigma$, or that the extreme limits of the population are:

$$\bar{X} + 3\sigma = .480 + 3 \times .0696 = \underline{.689} \text{ minute}$$
$$\bar{X} - 3\sigma = .480 - 3 \times .0696 = \underline{.271} \text{ minute}$$

Accordingly, it can be stated that the range of effort at the free choice pace, under stipulated conditions, is the ratio of the highest to the lowest, .689/.271 or 2.54:1.

Computation of Ordinate Values for Free Choice

Maximum Ordinate: $Y_o = \dfrac{.03 \times 74}{.0696 \times 2.5066} = \underline{12.7}$ frequencies

TABLE VIII

ORDINATE VALUES FOR NORMAL FREE CHOICE DISTRIBUTION CURVE

Ordinate Time Values x_1	x_2	x/σ	Appendix D[7] Factor	Ordinate Value (Frequency)
0	0			12.7
.450	.510	.432	.915	11.7
.420	.540	.864	.689	8.80
.390	.570	1.298	.429	5.5
.360	.600	1.728	.224	2.9
.330	.630	2.160	.097	1.3
.300	.660	2.582	.036	.5
.270	.690	3.338	.014	.2

7 Loc. cit.

Statistical Analysis of the Slowest Pace Times
for Straight Rotational Dealing

TABLE IX

COMPUTATION OF AVERAGE AND STANDARD DEVIATION OF FREQUENCY DISTRIBUTION FOR THE SLOWEST PACE

No.	Class	No. of Freq.(f)	Deviation from Assumed Mean(d')	f(d')	f(d')^2
1	.450-.509	1	-5	-5	25
2	.510-.569	5	-4	-20	80
3	.570-.629	9	-3	-27	81
4	.630-.689	10	-2	-20	40
5	.690-.749	7	-1	-7	7
6	.750-.809	9	0	0	0
7	.810-.869	7	1	7	7
8	.870-.929	5	2	10	20
9	.930-.989	3	3	9	27
10	.990-1.049	4	4	16	64
11	1.05- 1.109	0	5	0	0
12	1.11- 1.169	4	6	24	144
13	1.17- 1.229	3	7	21	147
14	1.23- 1.289	0	8	0	0
15	1.29- 1.349	0	9	0	0
16	1.35- 1.409	1	10	10	10
17	1.41- 1.469	0	11	0	0
18	1.47- 1.529	1	12	12	12
		69		30	886

Arithmetic Mean or Average of the Sample.

$$\overline{X} = .7795 + \frac{(30)}{69}.06 = .7795 + .026 = \underline{.806} \text{ minute}$$

Median of the Sample. Mid-point of all frequencies; N/2 = 69/2 = 34.5 frequencies. Since but 32 frequencies occur in the first 5 classes interpolation into the 6th class gives:

$$M = .7495 + \frac{(34.5 - 32)\ .06}{9} = .7495 + .016 = \underline{.766} \text{ minute}$$

Modal average of the Sample.

$$M_o = .6295 + \left[\frac{(10 - 9).06}{(10-9) - (10-7)}\right] = .6295 + .015 = \underline{.645} \text{ minute}$$

<u>Quartile Distribution of the Sample</u>. First Point: $Q_1 - N/4 = 69/4 = 17.25$ frequencies in the 1st quartile. Since but 15 frequencies occur in the 1st three classes interpolation into the 4th class gives:

$$Q_1 = .6295 + \frac{(17.25 - 15).06}{10} = .6295 + .0135 = \underline{.643} \text{ minute}$$

Mid-point: Q_2 = Median = $.\underline{766}$ minute

Third point: Q_3 at $3N/4 = 3 \times 69/4 = 51.8$ frequencies or 17.25 below the total number. Since but 16 frequencies occur in the last ten classes interpolation into the 8th class gives:

$$Q_3 = .9295 - \frac{(17 - 16).06}{5} = .9295 - .015 = \underline{.9145} \text{ minute}$$

<u>Skewness of the Sample Curve</u>.

$$Sk = \frac{3(.806 - .766)}{.213} = +\underline{.188} \text{ considerable skewness to right}$$

<u>Standard Deviation of the Population Estimated from Sample</u>

$$\bar{\sigma} = .06 \sqrt{\frac{886}{68} - \frac{(30)^2}{69 \times 68}} = .06 \sqrt{12.86} = \underline{.215} \text{ minute}$$

<u>Standard Error of the Mean</u>

$$\sigma_{\bar{x}} = .215 / \sqrt{69} = .215/8.3 = \underline{.0259} \text{ minute}$$

<u>Computation of Ordinate Values for the Normal Curve</u>

$$\text{Maximum Ordinate: } Y_o = \frac{69 \times .06}{.215 \times 2.5006} = 7.7 \text{ frequencies}$$

The values of the slow-pace times are too intermittent to attempt the establishment of a normal curve.

ANALYSIS AND INTERPRETATION OF RESULTS

Analysis and interpretation of the various statistical data indicated that studies of this nature can give useful information on the individual performance characteristics. Discussion of the findings, based on previously cited objectives follow.

1. What are the performance ranges at the various paces? The average performance ranges for group data at the designated deal paces and under controlled conditions described previously are as follows:

Fastest Pace	1.95 : 1
Incentive Pace	1.95 : 1
Normal Pace	1.75 : 1
Free Choice Pace	2.54 : 1
Slowest Pace	3.19 : 1

These values are believed to be representative of those on which Wechsler and Presgrave based their general indorsements that the range of average human effort is 2:1; the ratio of the fastest to the slowest performer.

By way of contrast, a group of seven subjects performing, first, as rapidly as possible and, secondly, at a slower pace were timed in the performance of both operations. The average range of effort for each of these paces was 1.22:1 and 1.26:1, respectively. (See Table 16) Times recorded for another group of nine subjects which operated at no given pace gave an average range of effort of 1.30:1. (See Table 18). Each of the frequency diagrams in each of these instances was either of marked bi-modal characteristic or strongly indicated such a trend[8].

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[8]Supra, p. 10.

There may be some significance in the fact that the average range of effort for the bi-modal type performance is less than that for the normal curve. Additional test data would be needed for the confirmation of such significance.

A study of the ordered times for the fastest-pace data of Table 11 revealed a distinct bi-modal characteristic with modes appearing, approximately, at .348 and .407 minutes, respectively. Performance of these same operators dealing at a slower pace revealed a bi-modal trend with modes appearing at, approximately, .402 and .454 minutes, respectively.

Another series of ordered cycle times for nine subjects (See Table 18) showed a marked bi-modal tendency with modes appearing at, approximately, .362 and .438 minutes, respectively.

Another development of interest was that of the grouping of the individual performance ranges for the separate paces. This is reflected in the tabulation shown below for which the data was taken from Tables 11, 12, 13, 14, and 15.

Ratio		No. Subjects by Ratio Interval, Each Pace.				
From	To	Fastest	Incentive	Normal	Free Choice	Slowest
1.03:1	1.03:1	0	5	3	4	5
1.04:1	1.06:1	10	14	14	18	7
1.07:1	1.09:1	15	19	19	15	18
1.10:1	1.12:1	19	12	9	14	16
1.13:1	1.15:1	8	8	15	9	9
1.16:1	1.18:1	9	4	7	6	4
1.19:1	1.21:1	3	3	2	0	1
1.22:1	1.24:1	6	3	1	5	1
over	1.25:1	3	5	3	2	5

It is considered significant that a majority of the subjects were grouped within a 15 per cent spread; that is, between 1.04:1 and

1.19:1. This is considered a good indication of performance consistency.

2. Can definite levels of performance be identified? The designation of performance levels cannot be done with complete confidence. However, the presence of such marked average or mean times as revealed from the various pace curves is considered indicative of definite levels. The cause for reservation will be discussed in a later paragraph. Acting on the conditional acceptance that levels are definable, the levels for the respective performance populations are as follows:

Pace	Limits in Minutes Maximum	Limits in Minutes Minimum	Mean Times	Standard Deviations
Fastest	.478	.246	.362	.0388
Incentive	.542	.280	.411	.0434
Normal	.592	.388	.465	.0423
Free Choice	.689	.271	.480	.0696
Slowest	1.451	.161	.806	.215

Although the slowest pace curve is lacking of normal distribution it is included in the tabulation for comparison purposes. The intermittent nature of the slow pace data, the large deviation factor, and widespread limits make such data of little value.

The chief reason for reservation on the validity of the performance level data can best be observed by study of curves in Figure 11. The overlapping effect of the curves is viewed as indicative of need for further investigation of those portions of the populations within the overlapped areas. Such study would certainly change the character of the remaining portions of the populations and is considered beyond the scope of this present effort. A subsequent analysis of this phase of the problem could well be included in a continuation study.

The confidence interval for the fastest tempo is .353 minutes to .371 minutes. This means that the mean or average times for at least 65 per cent of all samples of the same population will fall within those limits. Certain samples, not necessarily of the same population, have mean values very close to that for the fastest tempo data. One group of seven subjects dealing three cycles each had a mean value of .374 minute. A single operator dealing 53 continuous cycles had an average time per cycle of .377 minute. Another group of four persons dealing 160 hands of bridge had an average time of .367 minute per cycle. (See Tables 16 and 19.)

Three other tests; one for a group of seven subjects dealing at a pace <u>slower</u> that their fastest pace; another for a single operator dealing at a free choice rate; and still another group of nine subjects dealing at no designated pace had mean times of .438, .457, and .410 minutes, respectively. The first of these values lies between the confidence intervals for the incentive and normal paces. The second of these values lies within the confidence interval for the normal pace. The last of the values cited lies within the confidence interval for the incentive pace but as previously indicated the frecuency diagram is of bi-modal characteristic and the application of normal curve analysis is questionable. (See Tables 16, 20, and 18, respectively).

Since the mean or average times for the incentive and normal paces are so sharply defined it does appear that they may be indicative of definite levels of performance despite the lack of more complete verification. This sharply defined characteristic plus the definite separation of the respective means is rather convincing that there is not an infinite number of interveaning cycle times as is typical of continuous levels.

Tentative acceptance of the apparent existence of a definite incentive performance level seems warranted the mean value for which is located at approximately 13.5 per cent greater time value than that of the fastest pace mean.

The perculiar nature of the normal pace distribution curve raises doubt as to its being truly representative of the tempo. The distribution curve is one of negative skewness and that is not considered a normal situation. Distribution curves of negative skewness are attributable to unskill or to a composite of two frequency curves[9]. Figure 12 shows that the cumulative distribution ogive for the normal pace times crosses the free choice ogive at the mean or average time for the free choice time data. This may be indicative composite curve condition. On the other hand the near-parallelism of the normal-pace ogive gives impetus to the acceptance, tentatively, that the normal curve is very nearly an actual performance level. The mean or average time for this normal pace is approximately 13.2 per cent above the similar incentive-pace value.

The free choice distribution with its wide range is perhaps typical for an unmotivated operation. It does not possess sufficient distinction to warrant its consideration as a useful performance level

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[9] L. A. Sylvester, The Handbook of Advanced Time-Motion Study, New York: Funk and Wagnalls, 1950) p. 38.

teel. Its existence must be acknowledged, however.

The slowest pace data is believed to be too intermittent to be useful. Time data on a much greater number of subjects would be necessary for the establishment of useful curve.

3. <u>How many definite levels of performance can be identified</u>?

The fastest and incentive pace distribution curves are considered picturizations of definite levels. (See Figures 3 and 5). The normal curve is acceptable under reservation previously stated. (See Figure 7)

The lack of sharpness of the free choice curve makes it less dependable as an analytical instrument for work performance evaluation.

4. <u>What is the relationships between the various performance levels</u>? The presence of near equal percentage differences between the fastest and incentive curves and between the incentive and normal pace curves, 13.5 per cent and 13.2 per cent, respectively, is considered highly significant. The average time for the free choice pace is approximately 3.25 per cent higher than that for the normal curve. The nearly identical distribution curves for the fastest, incentive and normal paces is considered highly significant. (See Figure 11) This, in turn, produces maximum ordinate values of near equal magnitude 22.9, 20.4 and 21.1, respectively.

5. <u>What are the characteristics of each level</u>? Differences between the mean times and limit times for the various paces are as follows:

For	(1) Between Slowest and Free Choice	(2) Between Free Choice and Normal
$\overline{X}$	.806 - .480 = .326 min.	.480 - .465 = .015 min.
$\overline{X} + 3\sigma$	1.451 - .689 = .762 min.	.689 - .592 = .015 min.
$\overline{X} - 3\sigma$	.161 - .271 =-.111 min.	.271 - .338 =-.067 min.

For	(3) Between Normal and Incentive	(4) Between Incentive and Fastest
$\overline{X}$	.465 - .411 = .054 min.	.411 - .362 = .049 min.
$\overline{X} + 3\sigma$	.592 - .542 = .050 min.	.542 - .478 = .064 min.
$\overline{X} - 3\sigma$	.338 - .280 = .058 min.	.280 - .246 = .067 min.

There is a near constant difference noted between the normal and incentive paces but the order of the small differences is inverted by comparison with differences shown for the other three situations. That is, the $\overline{X}$ difference is greater than the $\overline{X} + 3\sigma$ difference and is less than the $\overline{X} - 3\sigma$ difference. With respect to the separate $\overline{X}$ values the differences can be expressed as: (1) $\pm$ 1.75$\overline{X}$, (2) $\pm$ 5.5 $\overline{X}$, (3) $\pm$ .926$\overline{X}$, and (4) $\pm$ 1.3$\overline{X}$. These differences in terms of their related $\overline{X}$ values are not great except for (3) the normal and incentive paces, $\pm$ 5.5$\overline{X}$.

Another important consideration is the relationships between standard deviations:

Relation		Differences
Fastest to Incentive	-	12.6 per cent greater
Incentive to Normal	-	3.2 per cent less
Normal to Free Choice	-	6.4 per cent greater
Free Choice to Slowest	-	200. per cent greater
Fastest to Normal	-	9.0 per cent greater
Fastest to Free Choice	-	87.0 per cent greater
Fastest to Slowest		454.0 per cent greater

6. <u>What are the relationships of individuals to each level?</u>

The relationship of individuals to each of the performance levels is a matter of high significance. (See Figure 14) Relative positions of individuals, based quartile data, with respect to the pace means are as follows:

(1) Of the numbers appearing in quartiles Q_1 and Q_2 for each of the various paces, redistribution with respect to the other paces occurs as indicated:

Q_1 and Q_2 to	Q_3 and Q_4	Per Cent
Incentive	Fastest	18.4
	Normal	30.6
	Free Choice	27.8
	Slowest	37.5
Normal	Fastest	36.9
	Incentive	34.2
	Free Choice	37.8
	Slowest	51.5
Free Choice	Fastest	26.3
	Incentive	29.7
	Normal	36.1
	Slowest	50.0
Fastest	Incentive	18.4
	Normal	35.2
	Free Choice	27.0
	Slowest	47.0

(2) Reverse study to show the redistribution of those individuals originally in Q_3 and Q_4 for each of the paces:

Q_1 and Q_2 to	Q_3 and Q_4	Per Cent
Incentive	Fastest	18.4
	Normal	34.2
	Free Choice	29.0
	Slowest	51.7
Normal	Fastest	29.8
	Incentive	29.7
	Free Choice	35.2
	Slowest	51.7

Q_1 and Q_2 to	Q_3 and Q_4	Per Cent
Free Choice	Fastest	27.0
	Incentive	27.0
	Normal	37.8
	Slowest	53.3
Fastest	Incentive	19.0
	Normal	35.2
	Free Choice	21.6
	Slowest	39.4

Broadly speaking, it appears that when the fastest and incentive pace are examined that there is a measure of consistency equal to about 80 per cent. Where the mid-range paces are involved it appears that the performance consistency is from 60 to 70 per cent and when the slowest pace times are viewed in connection with the mid-pace time values the consistency is a very poor 45 to 50 per cent. Motivated effort is definitely the more consistent.

8. What is the influence of method? Despite efforts to eliminate all possible variables some were, nevertheless, present throughout the tests. The chief method variable was that of the distance travelled by individual deal hands in disposing of cards from the deck into the respective boxes. The disposing techniques varied from wrist action with its minimum travel to the movement of the hand 10 to 12 inches for maximum travel. There were no means available by which the more subjective variables could be measured.

No material difference could be detected in average individual deal times attributable to the different distances that deal hands moved. It is therefore assumed that the rhythm factor to which the hand travel responded may have had offsetting influence on the different distance effects.

There was a noticeable relationship between card pick-up and deck reassembly times and the extent to which the deal hand moved in disposing of the cards. Wrist action deals scattered the cards rather badly in the boxes whereas the longer movements created a stacking effect and made the pick-up and assembly operations much easier.

It was thought that the use of the box receptables would stabilize the operation and have a retarding effect on cycle times. A comparison of the average fast-pace time, .362 minute, with the average cycle time for four players, dealing 160 hands, of .367 minute showed that this was a partially erroneous supposition.

Another effect of method on the cycle time requirements was that the time for dealing appeared to increase with even the slightest increase in the need for concentration and coordination. In one test 22 subjects were required to deal alternate hands in straight rotational and diagonal orders, as rapidly as possible. The average times were .426 minute for the straight cycle and .455 minute for the modified method. (See Table 21) This represented a six per cent increase. In another test involving seven subjects each individual dealt three consecutive rotational cycles and immediately repeated the three-cycle performance on the diagonal basis. Average cycle times for the separate methods were .391 minute and .395 minute, respectively, an increase of one per cent.

9. <u>Can it be established that the range is continuous or do definite increments exist?</u> Mean time values for the fastest and the incentive pace distributions and for the incentive and normal pace

distributions are separated by near uniform increments of 13.5 and 13.2 per cent, respectively. Increments appear to exist. (See Figure 11)

10. Predictability of the results? There is little favorable indication of the possible utilization of pace-time data in making predictions. Scatter diagrams of paired times, though indicating slight straight-line treads, are considered too scattered to be of great value. (See Figures 15 and 16)

CONCLUSIONS

1. The problem of determining the range of individual productivity is finite and of exceeding difficulty. Even though much progress has been made in the solution of the overall problem much remains to be done for properly evaluating the multitude of controversial issues that still prevail.

2. The bulk of the material on which the basic concepts appear to rest has been contributed by individuals and small groups indicating that no concerted industry-wide program has been devised nor have any plans for financing such a program been noted.

3. Based on results obtained from treatment of the raw data in this thesis it appears that definite levels of performance exist for given conditions. How all-inclusive these characteristics may be could well be the goal of subsequent experimentation and investigation.

4. Need for much additional data is clearly manifest. College level experiments are considered worthwhile as joint coordinated project undertakings. The advisability of having a single individual explore the problem is questioned because of the magnitude of the problem and the need for weighted opinions. This thesis can only be considered the first chapter of a planned program for further investigation effort.

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APPENDIX

TABLE X

ORDERED AVERAGE DEAL TIMES FOR EACH OF THE INDICATED PACES

Case No.	Deal Times in Minutes				
	Fastest	Incentive	Normal	Free Choice	Slowest
1	.293	.336	.368	.334	.461
2	.297	.336	.384	.349	.522
3	.303	.387	.387	.384	.535
4	.305	.342	.388	.387	.540
5	.308	.344	.390	.387	.552
6	.309	.347	.393	.389	.558
7	.309	.349	.409	.391	.585
8	.311	.353	.414	.403	.586
9	.314	.353	.415	.403	.587
10	.314	.354	.417	.408	.589
11	.316	.364	.425	.414	.594
12	.320	.365	.427	.421	.601
13	.322	.366	.431	.422	.610
14	.325	.368	.432	.428	.613
15	.326	.368	.433	.428	.620
16	.326	.374	.433	.429	.643
17	.330	.377	.438	.430	.650
18	.331	.378	.440	.432	.650
19	.333	.385	.442	.432	.650
20	.336	.385	.442	.433	.655
21	.336	.385	.443	.434	.668
22	.338	.385	.443	.436	.674
23	.340	.389	.443	.437	.676
24	.342	.392	.446	.442	.686
25	.344	.399	.450	.443	.687
26	.345	.400	.454	.447	.703
27	.345	.400	.455	.448	.710
28	.345	.401	.456	.450	.719
29	.346	.402	.458	.452	.723
30	.346	.404	.458	.453	.726
31	.346	.405	.458	.454	.742
32	.349	.406	.459	.456	.744
33	.351	.406	.460	.461	.752
34	.354	.407	.461	.463	.756
35	.355	.407	.461	.468	.763

TABLE X (cont'd)

ORDERED AVERAGE DEAL TIMES FOR EACH OF THE INDICATED PACES

Case No.	Deal Times in Minutes				
	Fastest	Incentive	Normal	Free Choice	Slowest
36	.356	.408	.462	.470	.763
37	.358	.408	.466	.470	.771
38	.359	.409	.468	.470	.773
39	.360	.409	.470	.472	.801
40	.361	.412	.471	.478	.805
41	.361	.413	.471	.478	.809
42	.364	.415	.472	.479	.812
43	.365	.415	.482	.479	.827
44	.365	.418	.473	.483	.830
45	.367	.419	.476	.487	.830
46	.369	.424	.476	.487	.842
47	.369	.426	.478	.490	.843
48	.369	.426	.480	.493	.864
49	.369	.427	.480	.493	.872
50	.370	.432	.482	.494	.898
51	.374	.433	.484	.496	.900
52	.376	.433	.484	.496	.905
53	.378	.434	.485	.496	.925
54	.381	.434	.487	.511	.948
55	.383	.435	.488	.512	.973
56	.385	.437	.490	.516	.973
57	.391	.438	.490	.519	1.000
58	.392	.440	.491	.519	1.013
59	.392	.444	.495	.524	1.015
60	.394	.445	.496	.530	1.042
61	.396	.449	.496	.532	1.113
62	.400	.454	.499	.538	1.117
63	.401	.456	.500	.543	1.128
64	.403	.458	.502	.547	1.133
65	.404	.466	.505	.562	1.171
66	.408	.468	.507	.562	1.197
67	.409	.469	.514	.564	1.216
68	.413	.478	.518	.575	1.397
69	.414	.483	.520	.611	1.474
70	.417	.484	.532	.614	

TABLE X (cont'd)

ORDERED AVERAGE DEAL TIMES FOR EACH OF
THE INDICATED PACES

Case	Deal Times in Minutes				
No.	Fastest	Incentive	Normal	Free Choice	Slowest
71	.424	.486	.544	.630	
72	.437	.498	.545	.632	
73	.450	.503	.556	.669	
74	.452	.517	.569	.678	

TABLE XI

AVERAGE AND INDIVIDUAL DEAL TIMES AT FASTEST PACE

Case No.	Deal Times in Minutes					
	Avg.	1	2	3	4	5
1	.354	.369	.370	.349	.341	.340
2	.381	.369	.370	.392	.374	.398
3	.417	.406	.421	.408	.436	.414
4	.401	.410	.426	.393	.377	.400
5	.322	.321	.305	.310	.336	.377
6	.330	.318	.327	.324	.343	.340
7	.303	.298	.322	.293	.295	.305
8	.376	.378	.380	.367	.368	.385
9	.361	.345	.352	.365	.359	.386
10	.396	.393	.409	.400	.404	.374
11	.424	.400	.445	.415	.434	-
12	.410	.400	.419	.405	.398	.426
13	.364	.370	.366	.368	.310	.405
14	.392	.400	.386	.386	.387	.399
15	.404	.381	.409	.398	.424	.406
16	.342	.350	.346	.334	.362	.320
17	.413	.418	.402	.381	.472	.392
18	.369	.380	.390	.351	.352	.370
19	.346	.356	.333	.357	.330	.354
20	.369	-	.305	.342	.437	.394
21	.314	-	.301	.330	.342	.283
22	.326	.355	.291	.301	.328	.353
23	.383	.386	.370	.401	.375	.381
24	.365	.354	.367	.355	.355	.394
25	.316	.291	.360	.326	.296	.305
26	.365	.344	.390	.344	.368	.378
27	.349	.350	.370	.342	.356	.329
28	.325	.322	.307	.293	.352	.351
29	.308	.326	.328	.293	.287	.307
30	.297	.297	.296	.301	.305	.288
31	.356	.338	.335	.371	.357	.381
32	.367	.367	.378	.375	.361	.352
33	.340	.329	.340	.338	.349	.346
34	.400	.397	.387	.388	.414	.415
35	.437	.444	.434	.432	.472	.402

TABLE XI (cont'd)

AVERAGE AND INDIVIDUAL DEAL TIMES AT FASTEST PACE

Case No.	Deal Times in Minutes					
	Avg.	1	2	3	4	5
36	.293	.278	.309	.288	.277	.311
37	.338	.340	.332	.334	.341	.344
38	.355	.354	.366	.361	.345	.348
39	.333	.331	.340	.337	.340	.316
40	.309	.290	.291	.320	.320	.325
41	.361	.320	.373	.365	.357	.391
42	.314	.297	.320	.311	.312	.330
43	.309	.270	.269	.297	.309	.401
44	.369	.387	.370	.348	.397	.341
45	.408	.392	.420	.420	.405	.405
46	.358	.336	.363	.359	.376	.355
47	.345	.342	.349	.331	.370	.334
48	.378	.365	.390	.360	.416	.357
49	.331	.342	.330	.340	.341	.301
50	.345	.308	.341	.360	.355	.360
51	.369	.360	.366	.350	.391	.377
52	.392	.401	.410	.391	.370	.389
53	.346	.38	.31	.34	.35	.35
54	.370	.35	.37	.36	.36	.41
55	.336	.302	.338	.348	.341	.350
56	.351	.323	.348	.357	.377	-
57	.385	.378	.400	.373	.402	.370
58	.305	.280	.330	.293	.329	.295
59	.311	.305	.308	.311	.310	.319
60	.319	.317	.328	.311	.321	-
61	.359	.338	.380	.356	.352	.368
62	.345	.351	.332	.345	.345	.352
63	.414	.407	.417	.420	.413	.435
64	.346	.341	.350	.365	.340	.322
65	.394	.384	-	.399	.390	.403
66	.344	.351	.336	.355	.340	.399
67	.374	.36	.39	.35	.39	.38
68	.336	.33	.36	.36	.32	.31
69	.326	.31	.33	.31	.34	.34
70	.403	.392	.404	.415	.385	.419
71	.360	.359	.374	.351	.352	.366
72	.391	.407	.408	.378	.377	.385

TABLE XII

AVERAGE AND INDIVIDUAL DEAL TIMES AT INCENTIVE PACE

Case No.	Deal Times in Minutes Avg.	1	2	3	4	5
1	.404	.408	.415	.400	.407	.392
2	.478	.462	.437	.466	.510	.512
3	.503	.522	.496	.519	.486	.490
4	.434	.417	.437	.412	.466	.437
5	.435	.404	.443	.432	.468	.427
6	.364	.361	.379	.360	.364	.358
7	.407	.378	.406	.411	.420	.419
8	.434	.429	.429	.446	.417	.447
9	.408	.425	.375	.412	.428	.400
10	.468	.440	.450	.482	.481	.485
11	.498	.494	.513	.497	.501	.484
12	.486	.458	.435	.445	.446	.446
13	.409	.425	.408	.395	-	.405
14	.432	.412	.420	.460	.422	.450
15	.392	.378	.394	.400	.400	.390
16	.458	.448	.474	.436	.474	.450
17	.400	.413	.407	.387	.390	.401
18	.377	.371	.445	.325	.382	.364
19	.466	.45	.49	.46	.47	.46
20	.353	-	.310	.355	.37	.381
21	.406	.414	.422	.395	.405	.395
22	.433	.450	.464	.429	.405	.417
23	.365	.373	.349	.356	.389	.358
24	.412	.40	.41	.416	.416	.420
25	.419	.430	.432	.424	.391	.419
26	.440	.41	.45	.46	.42	.46
27	.418	.45	.40	.45	.45	.34
28	.408	.40	.40	.39	.43	.42
29	.456	.42	.47	.46	.47	.46
30	.432	.38	.41	.46	.46	.45
31	.399	.410	.412	.400	.386	.388
32	.405	.393	.395	.402	.420	.415
33	.426	.425	.426	.423	.437	.420
34	.336	.303	.330	.362	.329	.355
35	.354	.341	.360	.356	.348	.365

TABLE XII (cont'd)

AVERAGE AND INDIVIDUAL DEAL TIMES AT INCENTIVE PACE

Case	Deal Times in Minutes					
No.	Avg.	1	2	3	4	5
36	.376	.348	.415	.366	.374	.379
37	.368	.389	.360	.362	.365	.366
38	.437	.437	.420	.448	.432	.450
39	.454	.448	.470	.440	.431	.479
40	.389	.369	.378	.395	.397	.406
41	.344	.347	.350	.348	.336	.339
42	.415	.372	.404	.420	.454	.423
43	.385	.386	.389	.390	.385	.377
44	.353	.341	.379	.360	.310	.374
45	.424	.376	.420	.420	.441	.461
46	.400	.410	.372	.392	.421	.403
47	.385	.340	.355	.391	.413	.424
48	.401	.435	.405	.398	.390	.375
49	.427	.437	.419	.445	.401	.431
50	.415	.440	.415	.416	.414	.392
51	.385	.379	.404	.390	.375	.379
52	.483	.516	.475	.473	.477	.473
53	.337	.347	.335	.347	.332	.322
54	.366	.371	.367	.364	.368	.361
55	.410	.406	.425	.395	.406	.416
56	.349	.353	.359	.341	.347	.345
57	.407	.408	.420	.405	.396	.406
58	.347	.317	.338	.353	.330	.398
59	.484	.426	.462	.488	.540	.504
60	.385	.362	.362	.394	.409	.400
61	.342	.32	.35	.35	.34	.35
62	.368	.38	.32	.38	.38	.38
63	.336	.35	.31	.35	.34	.33
64	.378	.36	.38	.36	.39	.40
65	.469	.478	.456	.510	.444	.455
66	.449	.435	.450	.435	.454	.471
67	.444	.449	.456	.446	.439	.432
68	.406	.404	.388	.413	.413	.412
69	.438	.427	.439	.445	.439	.442
70	.517	.536	.516	.538	.501	.493

TABLE XII (cont'd)

AVERAGE AND INDIVIDUAL DEAL TIMES AT INCENTIVE PACE

Case No.	Deal Time in Minutes					
	Avg.	1	2	3	4	5
71	.445	.436	.435	.447	.460	-
72	.413	.412	.408	.408	.418	.417
73	.426	.442	.429	-	.409	.423
74	.402	.408	.401	.406	.400	.393

TABLE XIII

AVERAGE AND INDIVIDUAL DEAL TIMES AT THE NORMAL PACE

Case No.	Deal Times in Minutes Avg.	1	2	3	4	5
1	.569	.564	.543	.614	.567	.556
2	.491	.453	.485	.534	.495	.49
3	.415	.398	.440	.411	.429	.398
4	.390	.419	.383	.386	.374	.390
5	.456	.441	.465	.498	.436	.439
6	.518	.549	.517	.485	.505	.534
7	.482	.477	.493	.489	.479	.474
8	.471	.469	.493	.457	.449	.485
9	.488	.47	.46	.47	.51	.53
10	.544	.52	.54	.53	.57	.56
11	.502	.52	.51	.52	.48	.48
12	.514	.50	.55	.50	.50	.52
13	.520	.52	.52	.52	.51	.53
14	.473	.457	.482	.473	.487	.467
15	.458	.460	.445	.466	.451	.469
16	.489	.500	.488	.472	.496	.493
17	.476	.485	.486	.467	.480	.462
18	.495	.521	.466	.500	.497	.481
19	.414	.441	.401	.400	.401	.413
20	.443	.440	.431	.442	.453	.448
21	.500	.511	.519	.497	.492	.479
22	.507	.545	.501	.511	.470	.500
23	.556	.581	.538	.556	.542	.562
24	.461	.472	.445	.441	.482	.466
25	.459	.458	.472	.464	.452	.448
26	.443	.440	.444	.438	.444	.450
27	.454	.442	.435	.465	.468	.458
28	.458	.461	.447	.464	.465	.452
29	.450	.425	.436	.460	.47	.46
30	.472	.450	.467	.473	.483	.489
31	.431	.416	.434	.432	.436	.436
32	.545	.516	.551	.532	.588	.539
33	.442	.471	.452	.446	.415	.425
34	.485	.547	.469	.452	.494	.465
35	.484	.450	.512	.490	.480	.488

TABLE XIII (cont'd)

AVERAGE AND INDIVIDUAL DEAL TIMES AT THE NORMAL PACE

Case No.	Deal Times in Minutes					
	Avg.	1	2	3	4	5
36	.470	.446	.454	.476	.479	.493
37	.500	.488	.506	.495	.500	.504
38	.460	.464	.440	.468	.468	.458
39	.388	.389	.395	.394	.373	.388
40	.433	.503	.455	.373	.416	.420
41	.468	.444	.500	.489	.440	.468
42	.533	.455	.500	.568	.580	.563
43	.387	.381	.381	.376	.375	.420
44	.433	.434	.435	.436	.427	.435
45	.466	.487	.485	.442	.450	.468
46	.446	.455	.450	.442	.455	.430
47	.409	.404	.415	.400	.405	.425
48	.505	.495	.524	.500	.502	.504
49	.417	.409	.382	.424	.420	.451
50	.458	.449	.428	.482	.455	.474
51	.432	.447	.417	.407	.504	.387
52	.487	.423	.455	.483	.506	.468
53	.496	.472	.487	.510	.471	.540
54	.425	.433	.450	.405	.400	.440
55	.484	.500	.468	.466	.504	.482
56	.384	.380	.360	.408	.380	.390
57	.393	.340	.435	.432	.403	.457
58	.438	.45	.45	.42	.47	.40
59	.442	.43	.40	.42	.41	.55
60	.478	.48	.47	.46	.48	.50
61	.472	.428	.482	.488	.489	.480
62	.480	.473	.493	.491	.481	.462
63	.461	.444	.466	.482	.446	.467
64	.440	.453	.460	.440	.426	.422
65	.443	.421	.425	.445	.462	.461
66	.368	.340	.351	.372	.385	.392
67	.476	.431	.467	.486	.492	.504
68	.427	.449	.427	.428	.423	.410
69	.455	.446	.454	.451	.460	.466
70	.471	.428	.467	.489	.498	-

TABLE XIII (cont'd)

AVERAGE AND INDIVIDUAL DEAL TIMES AT THE NORMAL PACE

Case No.	Deal Times in Minutes					
	Avg.	1	2	3	4	5
71	.480	.487	.485	.470	.466	.494
72	.462	.439	.472	.468	.467	.466
73	.496	.508	.518	.477	.500	.475
74	.490	.445	.482	.500	.498	.524

TABLE XIV

AVERAGE AND INDIVIDUAL DEAL TIMES AT FREE CHOICE PACE

Case No.	Avg.	Deal Times in Minutes 1	2	3	4	5
1	.461	.451	.451	.450	.495	.460
2	.430	.432	.435	.432	-	.422
3	.480	.459	.476	.478	.506	-
4	.391	.420	.415	.387	.370	.365
5	.487	.457	.482	.524	.497	.473
6	.443	.440	.434	.440	.456	.447
7	.456	.452	.486	.465	.438	.439
8	.442	.399	.428	.451	.437	.494
9	.429	.430	.458	.442	.409	.408
10	.428	.430	.426	.436	.422	.424
11	.519	.531	.506	.499	.539	.519
12	.387	.395	.361	.380	.390	.410
13	.437	.496	.442	.412	.432	.405
14	.496	.500	.480	.500	.523	.479
15	.532	.543	.544	.528	.532	.515
16	.611	.580	.602	.633	.635	.605
17	.538	.489	.549	.527	.561	.562
18	.478	.474	.495	.482	.471	.469
19	.632	.787	.779	.481	.482	-
20	.478	.490	.472	.467	.484	.479
21	.630	.576	.615	.582	.588	.591
22	.511	.479	.525	.513	.525	.511
23	.447	.434	.463	.441	.450	.448
24	.387	.400	.410	.378	.370	.379
25	.414	.420	.410	.410	.416	.415
26	.453	.439	.443	.448	.462	.473
27	.432	.441	.428	.446	.430	.417
28	.403	.396	.399	.415	.401	.406
29	.564	.584	.603	.548	.531	.556
30	.575	.534	.604	.606	.559	.570
31	.483	.505	.470	.469	.489	.480
32	.524	.566	.534	.504	.512	.506
33	.468	.464	.465	.465	.466	.479
34	.470	.492	.474	.464	.457	.462
35	.428	.415	.431	.438	.430	.425
36	.669	.555	.675	.671	.720	.722
37	.463	.452	.465	.460	.480	.458

TABLE XIV (cont'd)

AVERAGE AND INDIVIDUAL DEAL TIMES AT THE FREE CHOICE PACE

Case	Deal Times in Minutes					
No.	Avg.	1	2	3	4	5
38	.389	.361	.370	.395	.374	.404
39	.421	.410	.420	.390	.460	.425
40	.562	.512	.559	.551	.597	.592
41	.422	.451	.425	.429	.411	.395
42	.519	.533	.517	.505	.512	.526
43	.496	.505	.516	.505	.491	.461
44	.496	.500	.510	.500	.501	.470
45	.516	.46	.51	.56	.52	.53
46	.562	.58	.55	.57	.56	.55
47	.614	.58	.62	.61	.63	.63
48	.494	.47	.48	.48	.51	.53
49	.452	.482	.46	.48	.41	.43
50	.530	.51	.52	.53	.55	.54
51	.403	.41	.35	-	.42	.43
52	.436	.41	.46	.42	.47	.42
53	.408	.41	.40	.38	.40	.45
54	.448	.46	.45	.47	.43	.43
55	.678	.637	.621	.633	.771	.726
56	.512	.477	.404	.550	.545	.582
57	.479	.468	.492	.483	.462	.492
58	.472	.476	.476	.464	-	-
59	.432	.450	.445	.400	-	-
60	.454	.463	.442	.458	-	-
61	.450	.433	.467	.449	-	-
62	.349	.349	.338	.357	-	-
63	.384	.421	.367	.363	-	-
64	.334	.325	.351	.326	-	-
65	.434	.440	.425	.437	-	-
66	.433	.421	.461	.417	-	-
67	.490	.51	.48	.48	-	-
68	.493	.49	.50	.49		
69	.543	.51	.57	.55		
70	.493	.53	.47	.48		
71	.547	.55	.53	.56		
72	.470	.48	.47	.47		
73	.487	.47	.51	.48		
74	.470	.48	.46	.47		

TABLE XV

AVERAGE AND INDIVIDUAL DEAL TIMES AT THE SLOWEST PACE

Case No.	Deal Times in Minutes Avg.	1	2	3	4	5
1	.812	.845	.881	.802	.779	.753
2	.752	.717	.740	.749	.785	.771
3	.872	.808	.848	.895	.881	.927
4	1.216	1.178	1.208	1.213	1.251	1.232
5	.925	.923	.957	.892	.950	.902
6	.773	.789	.802	.758	.769	.746
7	.973	.927	.939	1.000	1.030	.970
8	1.015	1.000	1.016	1.090	1.025	.945
9	1.171	1.072	1.131	1.196	1.217	1.240
10	1.113	1.110	1.153	1.072	1.105	1.124
11	.948	.892	.935	.953	.982	.976
12	.905	.880	.925	.875	.870	.976
13	.540	.590	.535	.535	.521	.521
14	.589	.554	.627	.576	.575	.615
15	.613	.641	.600	.592	.617	.615
16	.585	.599	.595	.597	.578	.555
17	.655	.683	.676	.672	.613	.630
18	.620	.66	.61	.62	.60	.61
19	.650	.60	.74	.67	.64	.60
20	.643	.63	.65	.65	-	-
21	.461	.461	.470	.467	.458	.450
22	.535	.565	.529	.532	.507	.540
23	.587	.610	.555	.605	.590	.575
24	.522	.448	.570	.585	.527	.532
25	.558	.474	.555	.579	.562	.620
26	.898	.91	.90	.93	.85	.90
27	.842	.800	.952	.818	.806	.834
28	.586	.534	.641	.586	.61	.562
29	1.128	.81	.951	1.050	1.060	1.193
30	1.197	1.165	1.350	1.150	1.150	1.170
31	.676	.67	.64	.69	.67	.71
32	.668	.73	.65	.65	.66	.65
33	.594	.65	.60	.57	.57	.58
34	.744	.736	.734	.721	.774	.754
35	.686	.669	.659	.703	.733	.668

TABLE XV (cont'd)

AVERAGE AND INDIVIDUAL DEAL TIMES AT THE SLOWEST PACE

Case No.	Deal Times in Minutes Avg.	1	2	3	4	5
36	.805	.970	.842	.752	.746	.713
37	.710	.70	.69	.74		
38	.830	.79	.86	.84		
39	.763	.76	.74	.79		
40	.830	.83	.82	.84		
41	.610	.62	.60	.61		
42	.723	.71	.71	.75		
43	.843	.81	.87	.85		
44	.827	.77	.84	.87		
45	.650	.67	.67	.61		
46	.687	.68	.68	.70		
47	.650	.67	.63	.65		
48	.552	.558	.548	.550		
49	.601	.594	.636	.573		
50	.756	.729	.762	.776		
51	.703	.785	.695	.728		
52	.726	.606	.776	.797		
53	1.042	1.002	1.085	1.039		
54	1.474	1.447	1.495	1.480		
55	.801	.706	.836	.862		
56	.719	.685	.715	.757		
57	.900	.846	.908	.946		
58	.864	.828	.893	.870		
59	.771	.724	.792	.798		
60	.742	.795	.777	.655		
61	.647	.654	.694	.675		
62	.763	.731	.771	.788		
63	1.117	1.190	1.000	1.160		
64	1.397	1.150	1.480	1.560		
65	1.000	1.020	.980	1.000		
66	1.133	1.200	1.080	1.120		
67	.973	1.000	1.030	.890		
68	1.013	.960	1.080	1.000		
69	.809	.784	.837	.807		

TABLE XVI

AVERAGE AND INDIVIDUAL DEAL TIMES FAST AND SLOWER PACES

Operator No.	Avg.	1	2	3
1	.406	.41	.42	.39
2	.346	.36	.35	.35
3	.334	.35	.33	.32
4	.406	.42	.39	.41
5	.352	.35	.34	.36
6	.367	.37	.37	.36
7	.408	.41	.41	.40
X	.374			
Average Range of Effort 1.22:1			σ = .0337	
A Slower Pace - Same Operators				
1	.500	.50	.50	.50
2	.396	.40	.38	.41
3	.408	.41	.39	.42
4	.446	.43	.46	.46
5	.402	.40	.41	.41
6	.456	.45	.45	.47
7	.452	.46	.45	.45
X	.438			
Average Range of Effort 1.26:1			σ = .0281	

TABLE XVII

INDIVIDUAL CYCLE TIMES, STRAIGHT ROTATIONAL AND DIAGONAL-FAST

No.	Operator No. 1 Straight	Operator No. 1 Diagonal	Operator No. 2 Straight	Operator No. 2 Diagonal
1	.415	.445	.421	.444
2	.426	.428	.473	.418
3	.442	.430	.415	.410
4	.423	.512	.400	.400
5	.438	.462	.410	.407
6	.447	.413	.382	.405
7	.447	.445	.347	.402
8	.410	.423	.417	.429
9	.448	.430	.370	.382
10	.440	.453	.369	.382
11	.450	.443	.368	.350
12	.486	.435	.360	.358
13	.444	.381	.368	.388
14	.461	.438	.347	.383
15	.449	.488	.417	.370
$\bar{X}$	.442	.442	.391	.395
σ	.0215	.0337	.0261	.0183

TABLE XVIII

AVERAGE AND INDIVIDUAL TIMES, NO SPEED INDICATED IN ORIGINAL INSTRUCTIONS

No.	Avg.	1	2	3
1	.440	.42	.45	.44
2	.394	.40	.41	.38
3	.427	.44	.42	.41
4	.360	.36	.36	.36
5	.444	.42	.44	.47
6	.364	.35	.36	.38
7	.362	.37	.35	.36
8	.430	.43	.43	.43
9	.468	.47	.48	.45
$\bar{X}$	.410			
σ	.0398			

TABLE XIX

SINGLE CYCLE DEAL TIMES - SINGLE OPERATOR DEALING
STRAIGHT ROTATIONAL - FASTEST PACE

No.	Time in Min.	No.	Time in Min.	No.	Time in Min.
1.	.355	19.	.397	37.	.361
2.	.366	20.	.394	38.	.358
3.	.373	21.	.389	39.	.361
4.	.403	22.	.370	40.	.368
5.	.373	23.	.428	41.	.378
6.	.378	24.	.380	42.	.368
7.	.377	25.	.368	43.	.372
8.	.367	26.	.394	44.	.377
9.	.372	27.	.382	45.	.368
10.	.370	28.	.370	46.	.385
11.	.391	29.	.371	47.	.340
12.	.367	30.	.360	48.	.407
13.	.376	31.	.335	49.	.393
14.	.400	32.	.399	50.	.377
15.	.390	33.	.369	51.	.387
16.	.381	34.	.363	52.	.362
17.	.383	35.	.373	.53	.385
18.	.378	36.	.375		

$\overline{X}$ = .377 minutes σ = .017
Performance Range 1.26:1

TABLE XX

SINGLE CYCLE DEAL TIMES - SINGLE OPERATOR DEALING
STRAIGHT ROTATIONAL - FREE CHOICE PACE

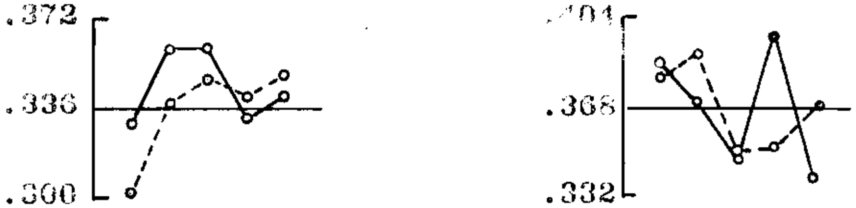
No.	Time in Min.	No.	Time in Min.	No.	Time in Min.
1.	.407	11.	.436	21.	.465
2.	.412	12.	.485	22.	.435
3.	.425	13.	.464	23.	.457
4.	.442	14.	.440	24.	.488
5.	.470	15.	.451	25.	.475
6.	.453	16.	.431	26.	.464
7.	.466	17.	.470	27.	.471
8.	.439	18.	.475	28.	.472
9.	.472	19.	.490	29	.474
10.	.480	20.	.489		

$\overline{X}$ = .457 minutes
Performance Range 1.20:1 σ = .024

TABLE XXI

AVERAGE DEAL TIMES BY ALTERNATE METHODS: (1) STRAIGHT ROTATION AND (2) ON DIAGONALS BETWEEN BOXES AT FASTEST POSSIBLE PACE

Case No.	Avg. Time in Min.	Case No.	Avg. Time in Min.
	Straight Rotation		
1	.550	12	.382
2	.490	13	.458
3	.390	14	.442
4	.414	15	.436
5	.448	16	.408
6	.454	17	.418
7	.392	18	.402
8	.394	19	.404
9	.437	20	.392
10	.434	21	.392
11	.410	22	.398
$\bar{X}$			.425
	On the Diagonals Between Boxes		
1	.594	12	.394
2	.480	13	.490
3	.420	14	.490
4	.424	15	.475
5	.463	16	.444
6	.504	17	.442
7	.424	18	.418
8	.433	19	.475
9	.444	20	.410
10	.484	21	.475
11	.410	22	.432
$\bar{X}$			.460



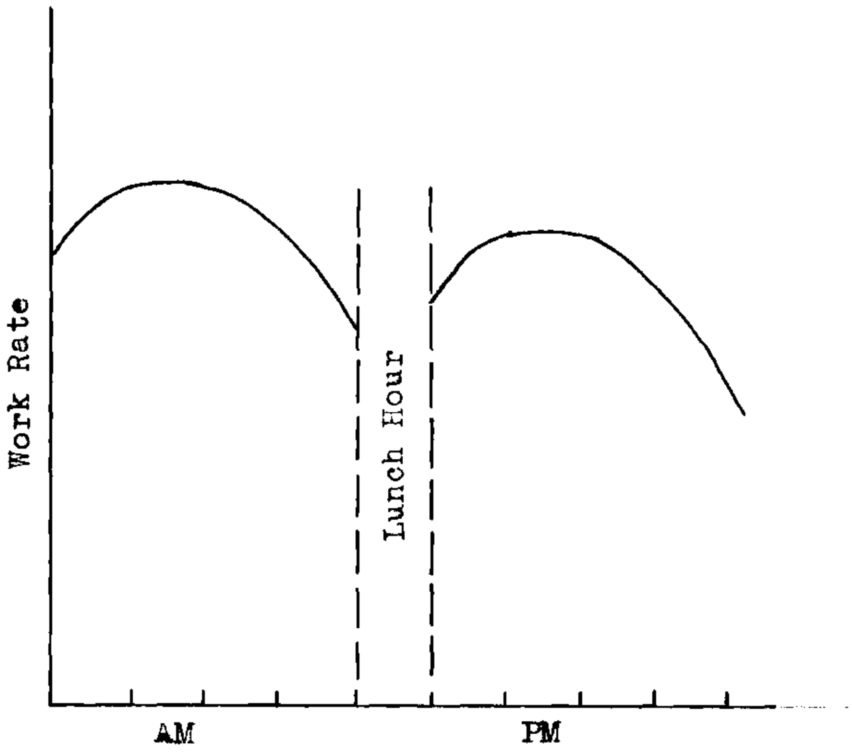
Typical of Fastest Pace

Typical of Incentive Pace

Typical of Normal Pace

Typical of Free Choice Pace

Figure 1 - Chart Showing Individual Inconsistency for Five Repetitive Card Deals



Source: Viteles

Figure 2 - A Typical Production Courve for Manual Effort.

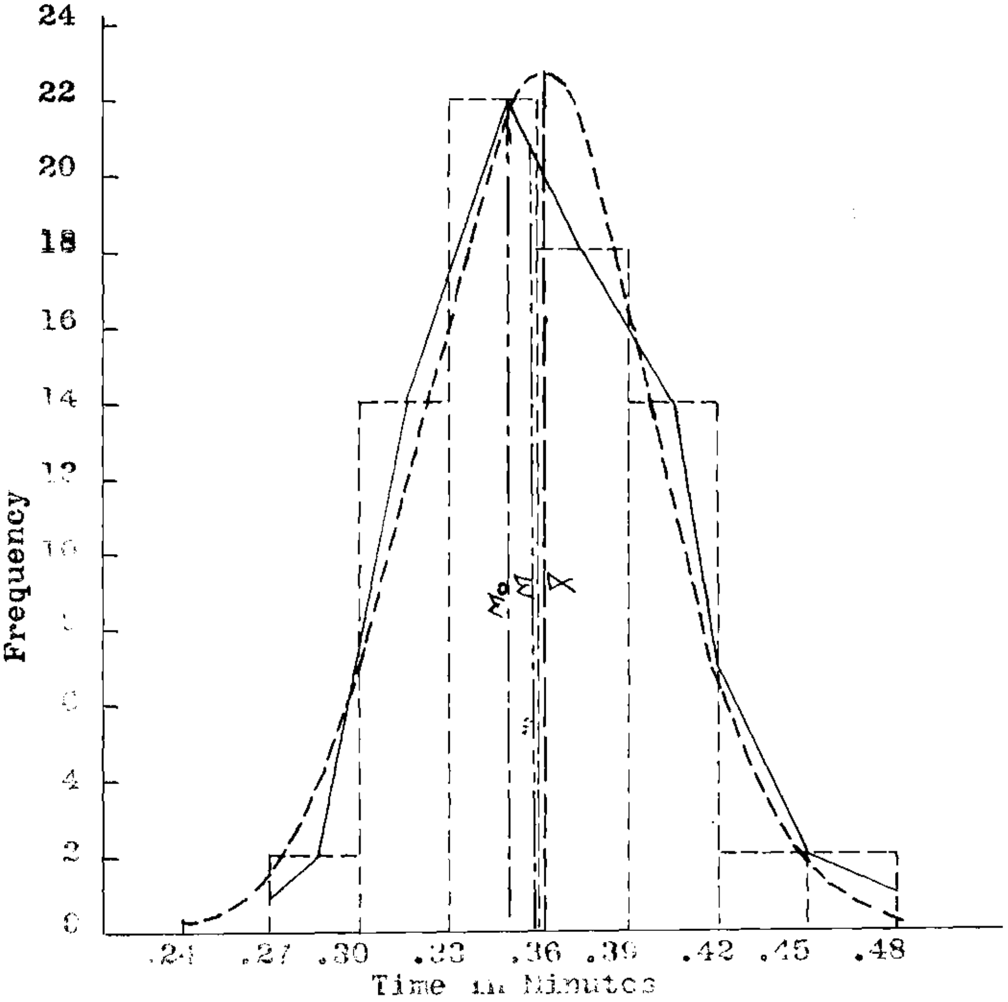


Figure 3 - Chart Showing Frequency Diagram and Normal Curve - Fastest Pace

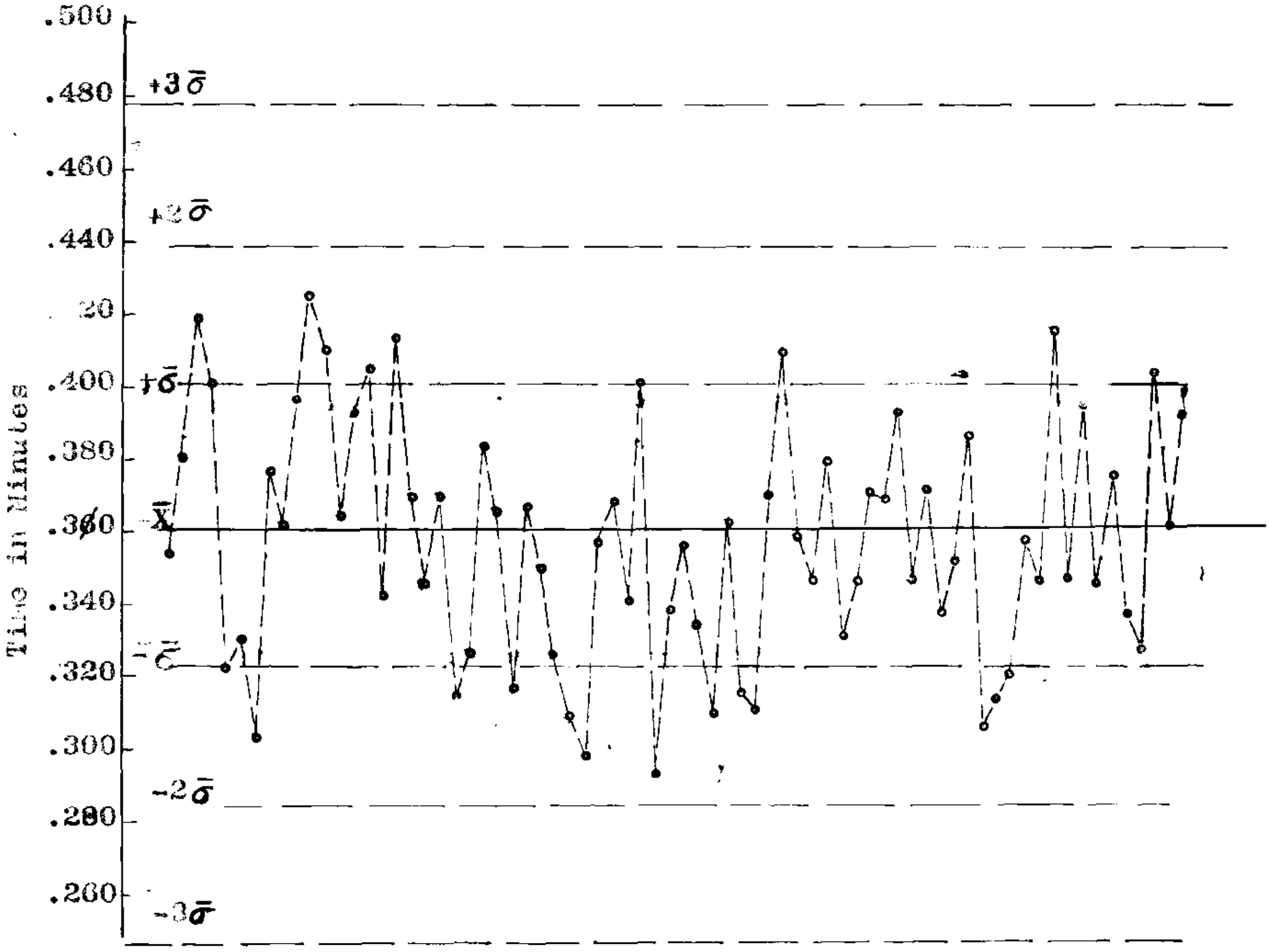


Figure 4 - Control Chart Showing Individual Deviations from the Sample Mean - Fastest Pace

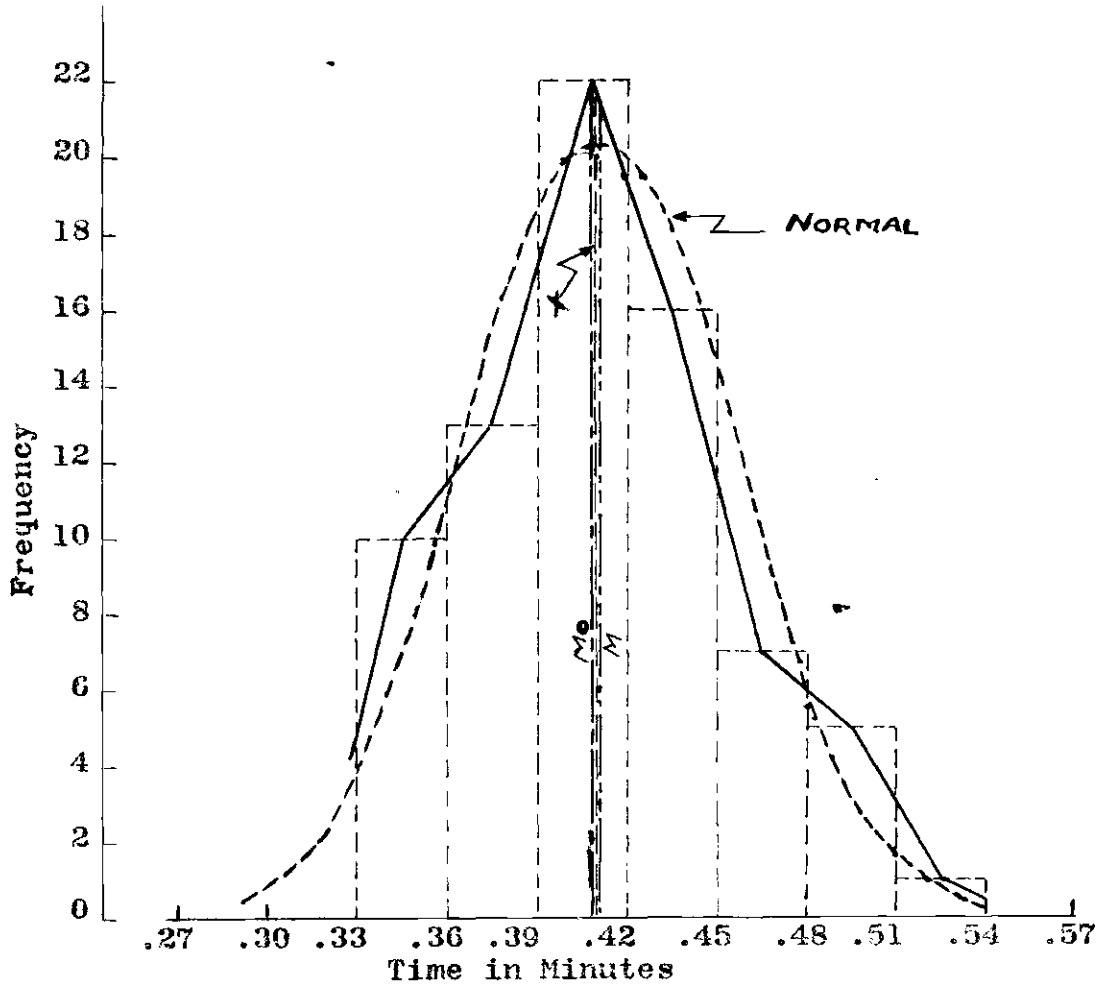


Figure 5 - Frequency Diagram and Curve for Incentive Pace

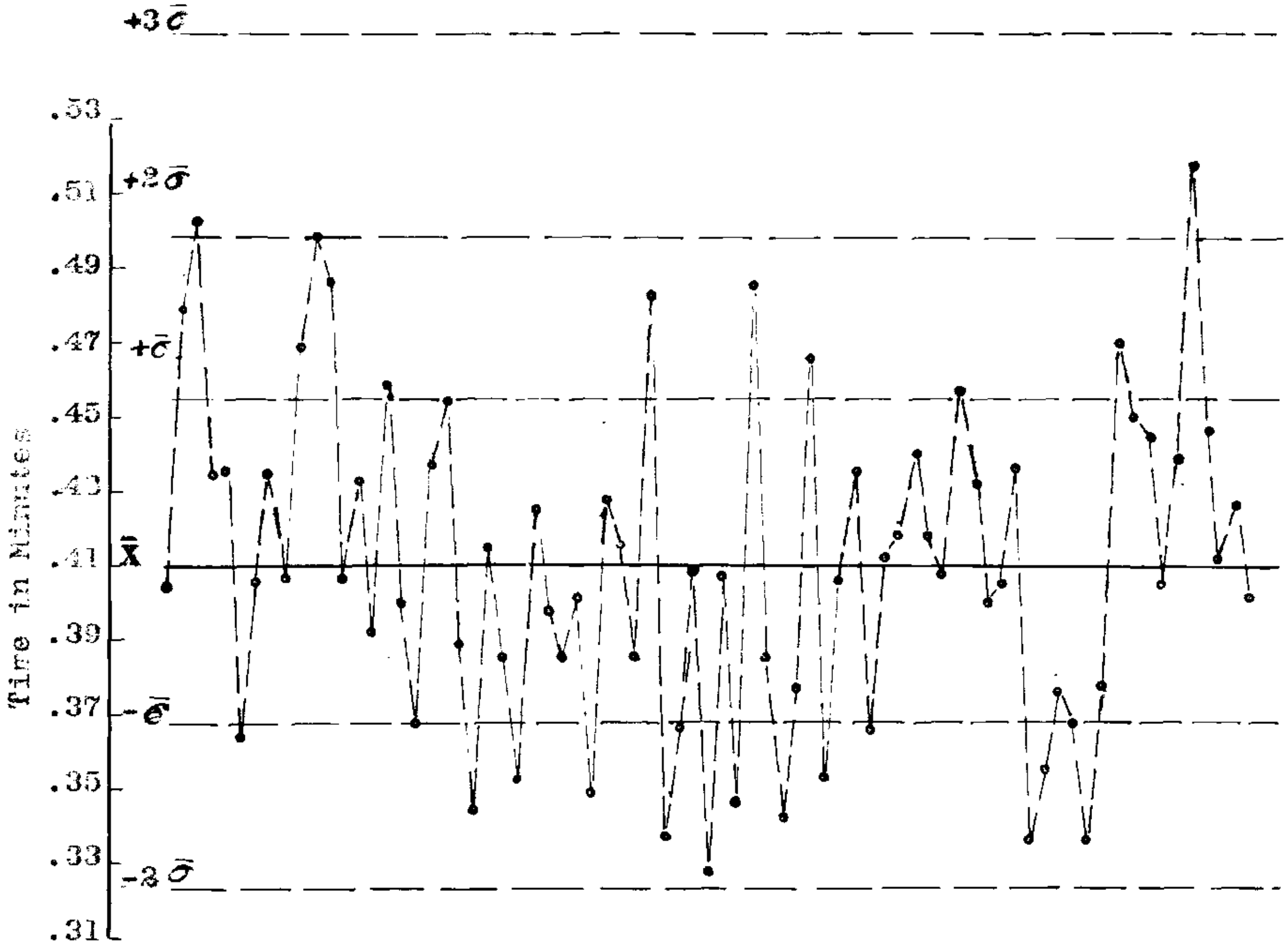


Figure 6 - Control Chart Showing Individual Deviations from the Sample Mean - Incentive Pace

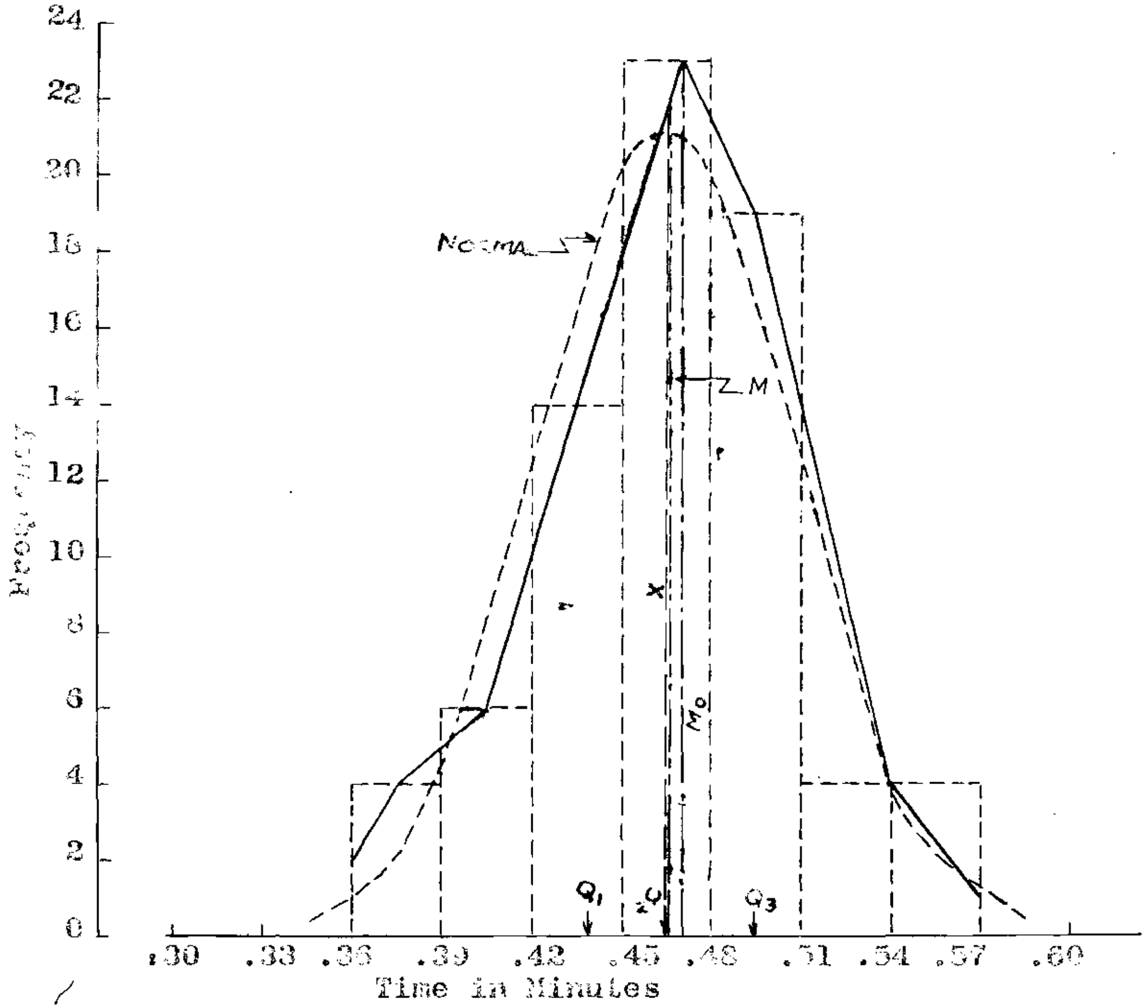


Figure 7 - Frequency Diagram and Curve for Normal Pace

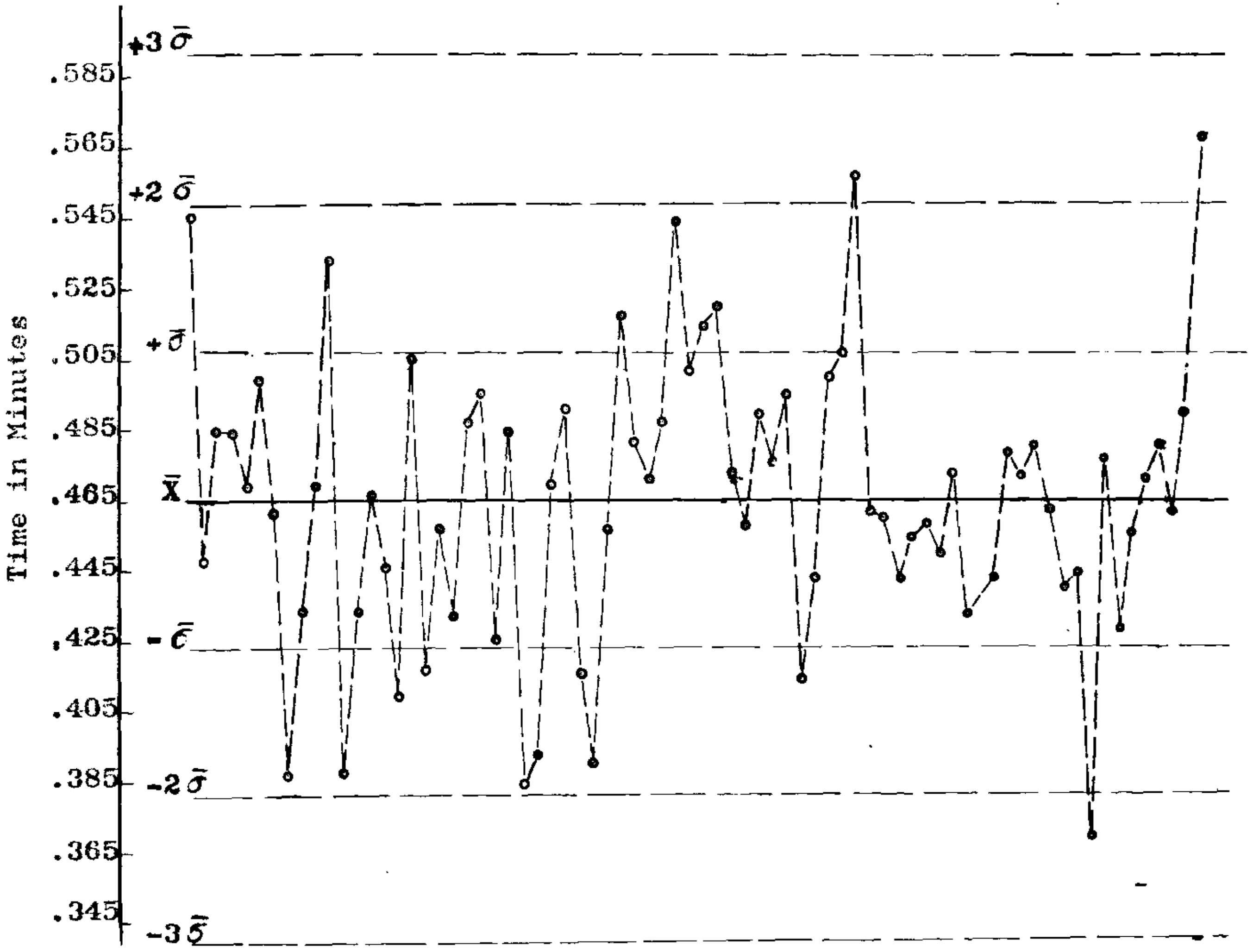


Figure 8 - Control Chart Showing Individual Deviations from the Sample Mean - Normal Pace

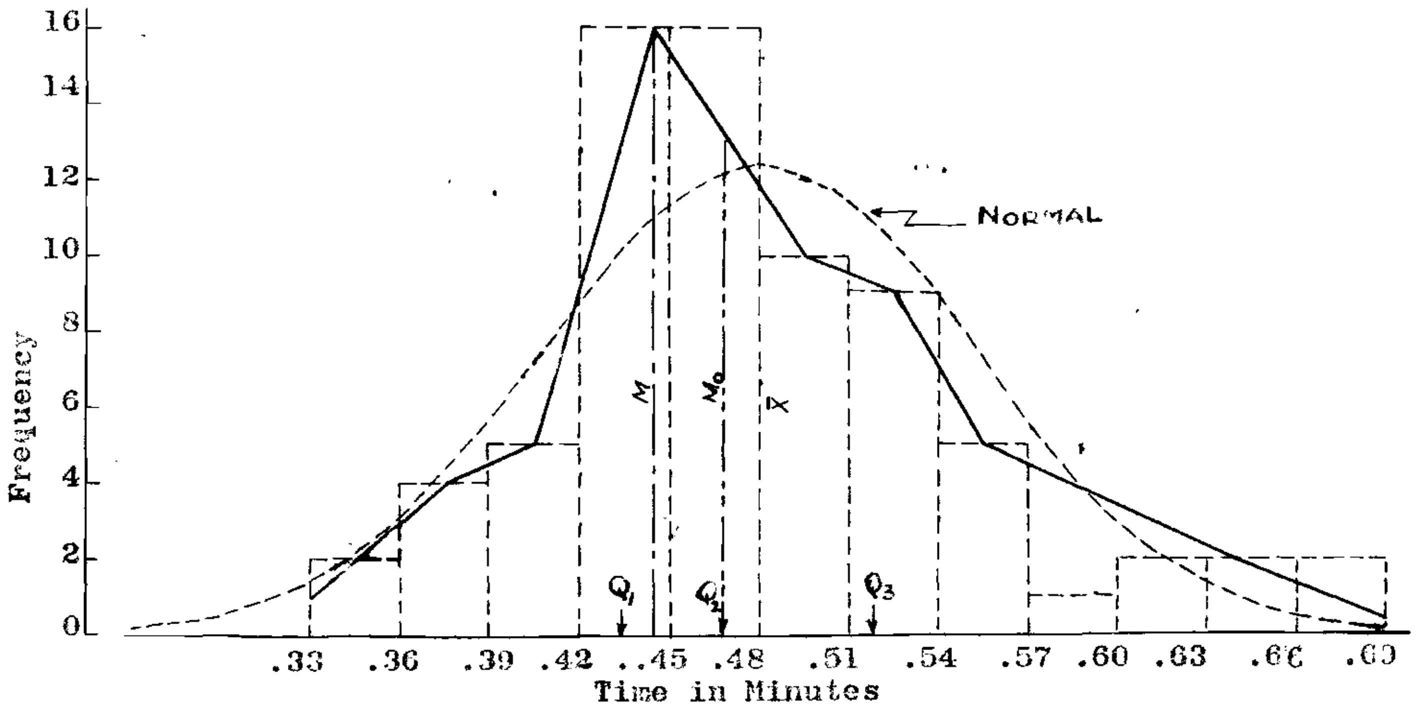


Figure 9 - Frequency Diagram and Curve for Free Choice Pace

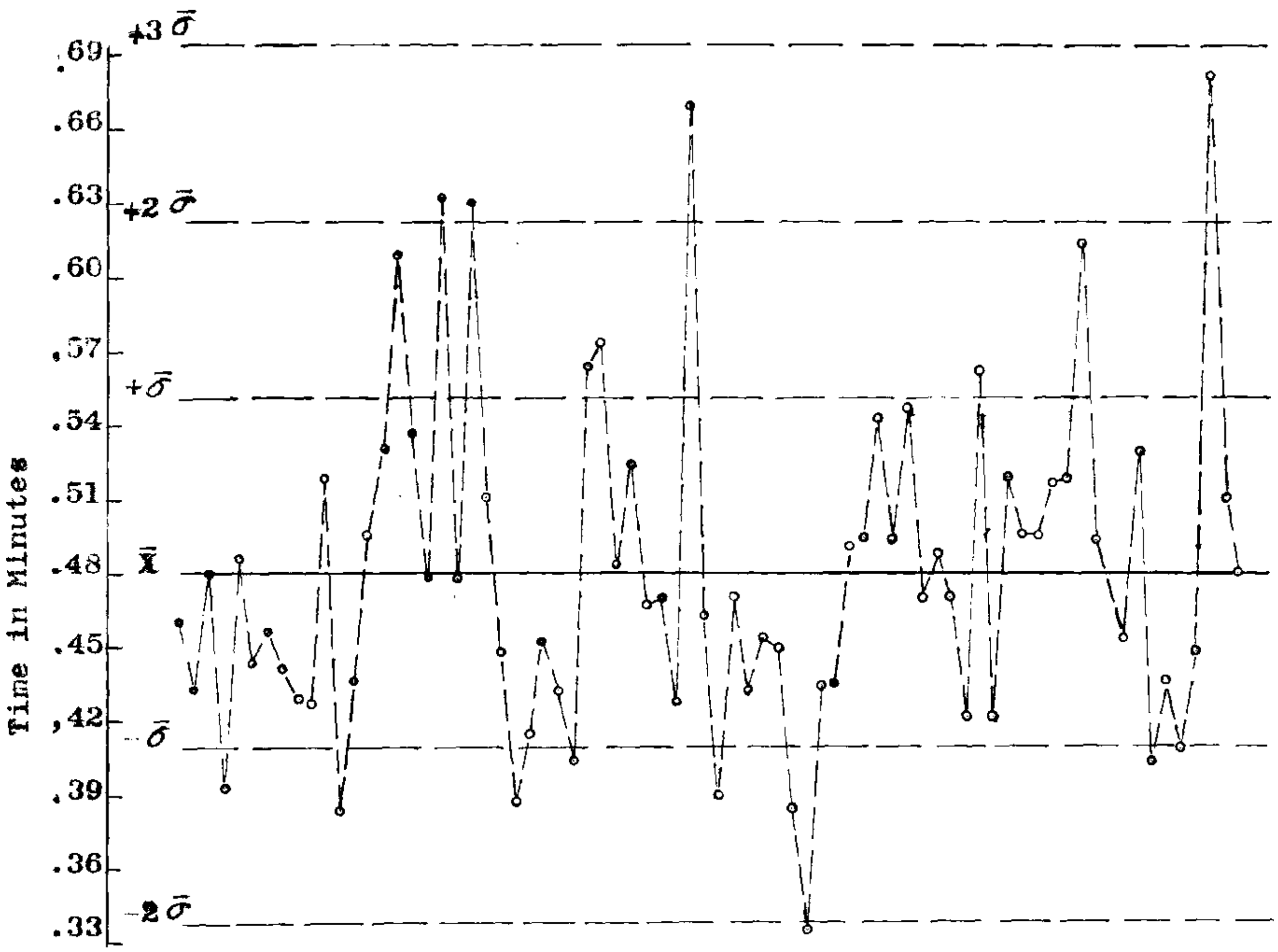


Figure 10 - Control Chart Showing Individual Deviations from the Sample Mean - Free Choice Pace

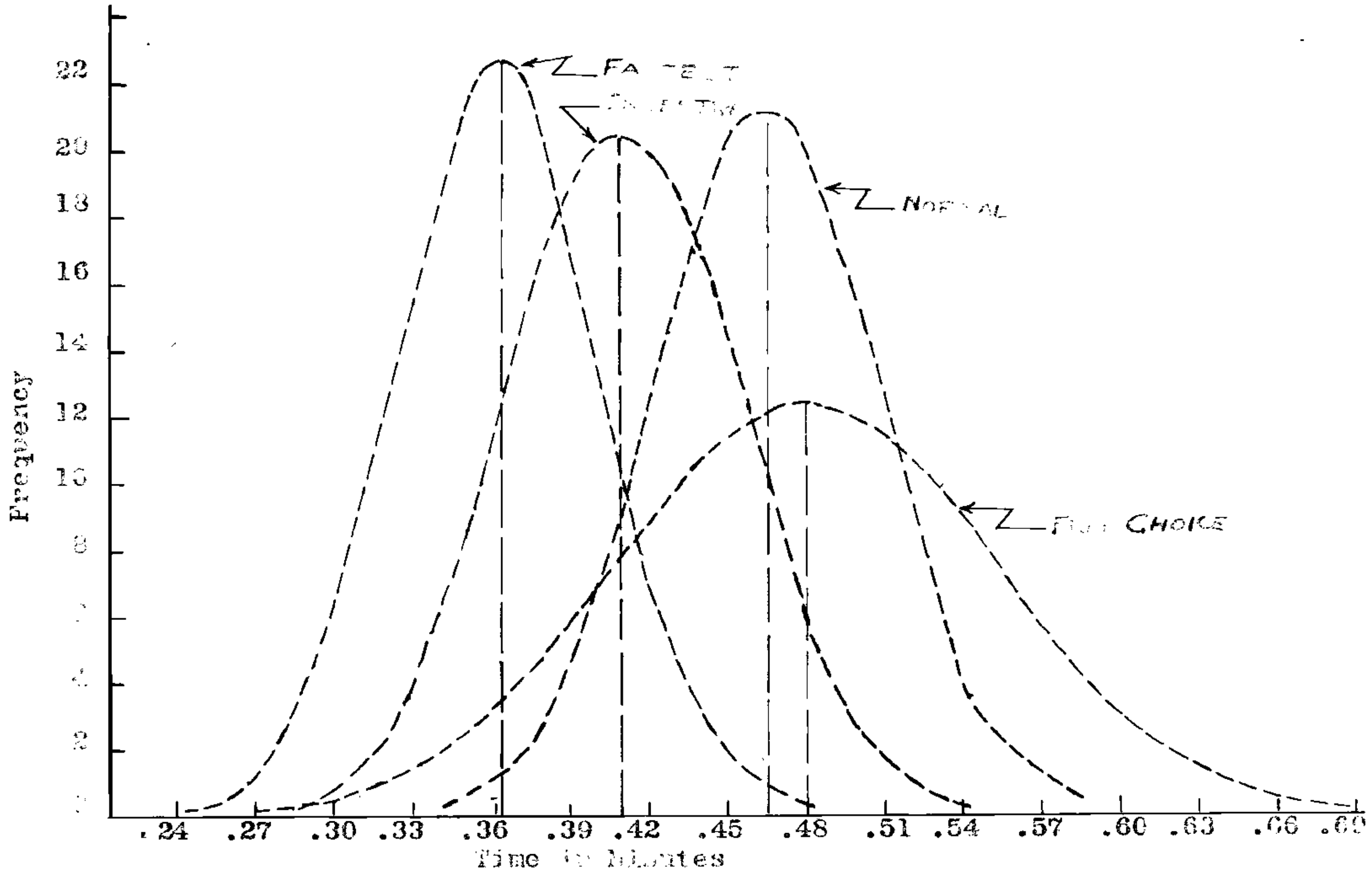


Figure 11 - Chart Showing [illegible] for Curves at Various Speeds

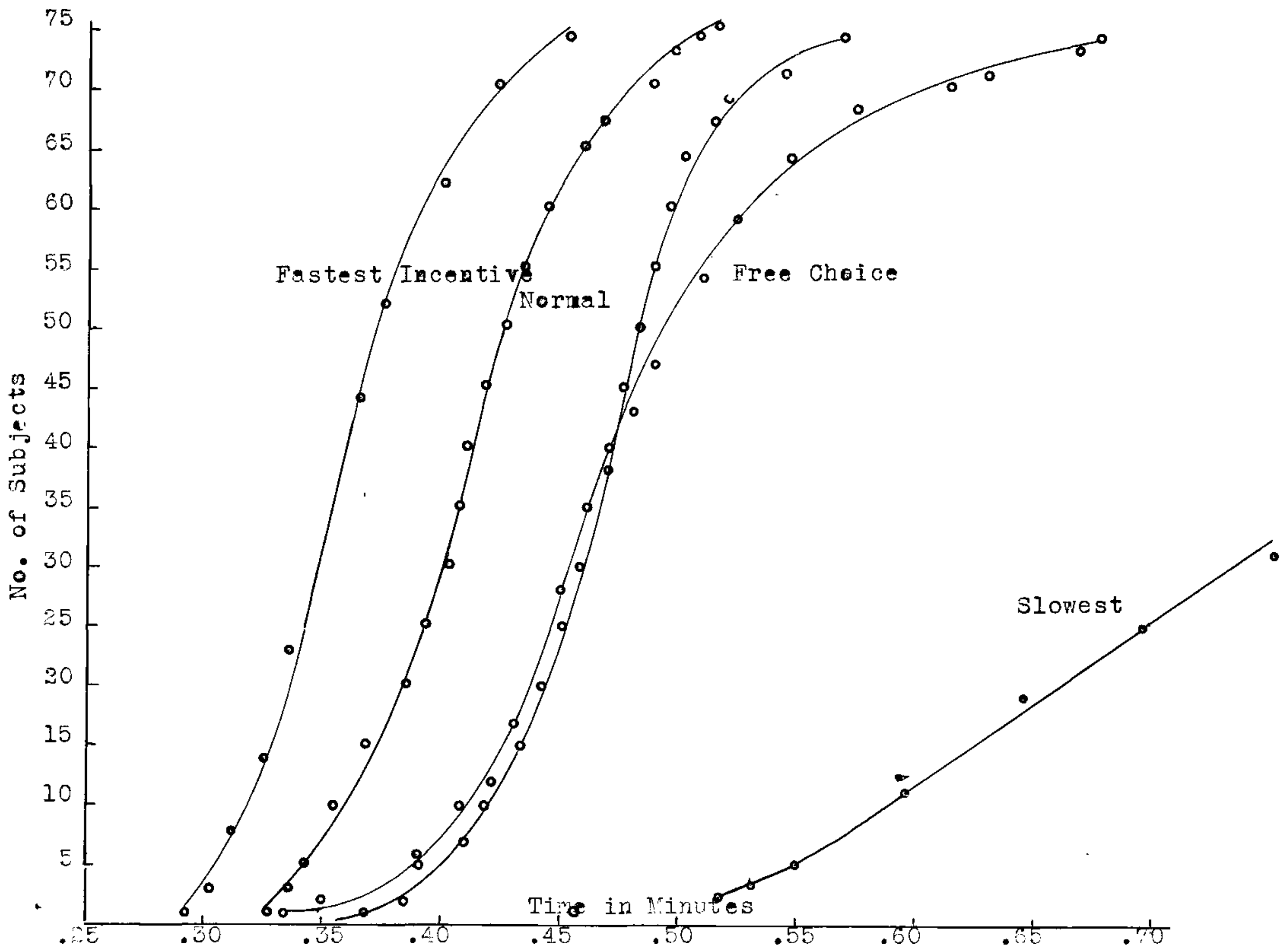


Figure 12 - Cumulative Distribution Curves for Individual Time Data for the Various Deal Paces.

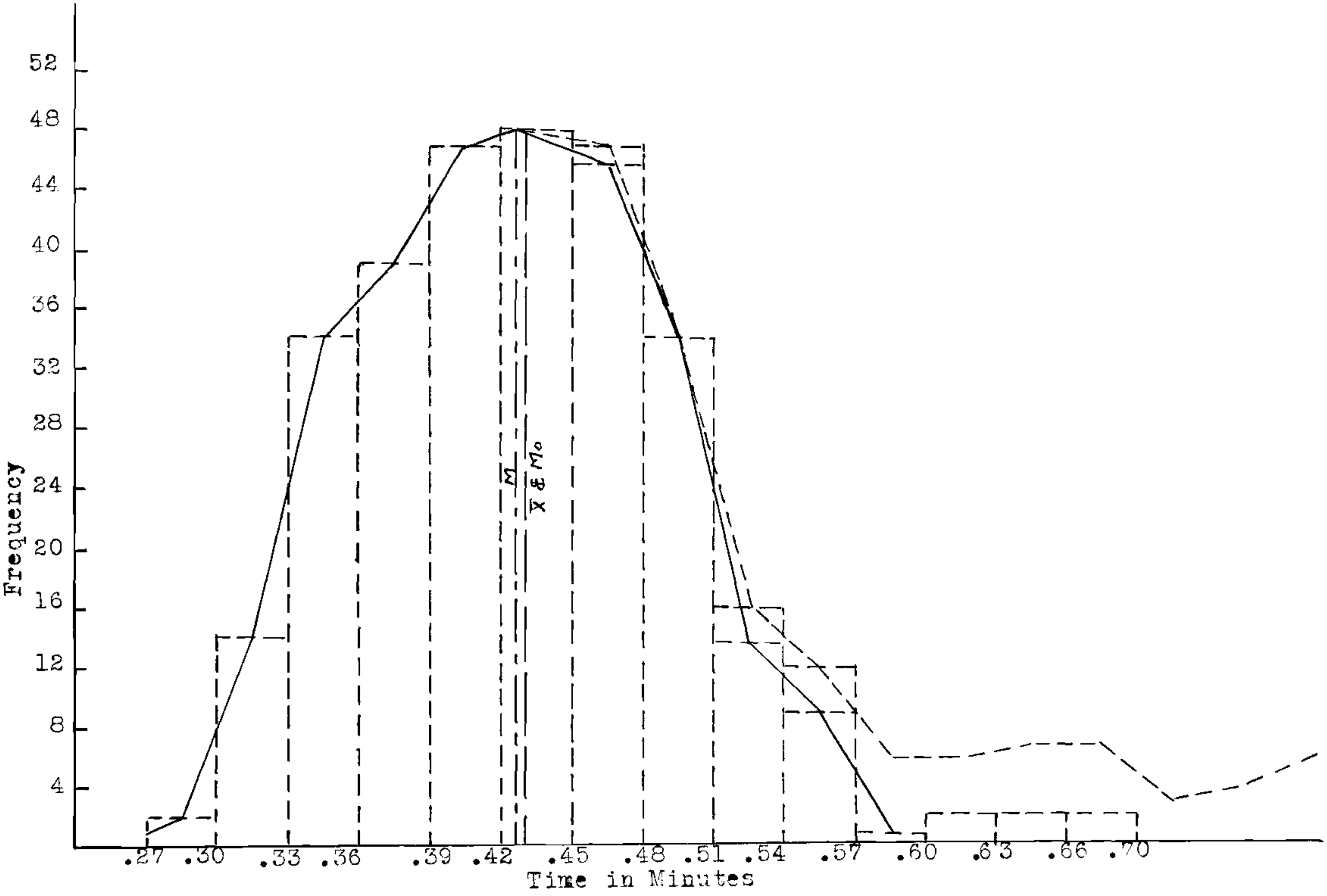


Figure 13 - Composite Frequency Diagram for All Average Time Data at the Various Paces and Showing the Separate Effect of the Slowest Pace Data.

	Incentive				Normal				Free Choice				Fastest				Slowest			
No.	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4
1	O						X			X			O							
2	X				X				X				X					X		
3	X				X						X		X					X		
4	X				X							X	X					X		
5	X				X				X				X							
6	X						X					X	X					X		
7	X				X				X				X				X			
8	X				X				X				X				X			
9	X					X			X				X					X		
10	X				X				X					X					X	
11	X					X				X			X					X		
12	X				X				X				X							X
13	X							X	X				X				X			
14	X					X					X			X			X			
15	X				X					X				X			X			
16	X							X		X			X							
17	X				X					X			X						X	
18	X					O				X					X		X			
19	X						X			X					X			X		
20		X						X		X			X							
21		X										X			X		X			
22		X			X				X					X			X		X	

Figure 14

Quartile Distribution of Individual Averages for All Paces

No.	Incentive				Normal				Free Choice				Fastest				Slowest			
	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4
23		X			X					X			X							X
24		X					X					X			X			X		
25		X				X				X				X						X
26		X								X				X				X		
27		X					X				X			X						
28		X				X								X						
29		X			X				X				X				X			
30		X													X					X
31		X					X				X			X					X	
32		X				X			X					X				X		
33		X				X				O					X					X
34		X			X				X					X			X			
35		X				X			X				X						X	
36		X						X		X				X				X		
37		X						X				X		X				X		
38		X			X					X					X				X	
39			X			X						X			X					X
40			X		X						X			X				X		
41			X				X					X		X			X			
42			X				X		X					X						X
43			X				X				X				X					
44			X			X			X						X		X			
45			X				X					X				X		X		

Figure 14 (cont'd)

Quartile Distribution of Individual Averages for All Paces

No.	Incentive Q_1	Incentive Q_2	Incentive Q_3	Incentive Q_4	Normal Q_1	Normal Q_2	Normal Q_3	Normal Q_4	Free Choice Q_1	Free Choice Q_2	Free Choice Q_3	Free Choice Q_4	Fastest Q_1	Fastest Q_2	Fastest Q_3	Fastest Q_4	Slowest Q_1	Slowest Q_2	Slowest Q_3	Slowest Q_4
46			X				X				X				X			X		
47			X		X			X		X				X						
48			X					X	X						X					X
49			X			X				X						X				X
50			X			X				X				X			X		X	
51			X					X			X					O				
52			X			X					X					X				X
53			X			X						X			X		X			
54			X				X				X					X			X	
55			X				X			X						X		X		
56			X					X	X				X							X
57			X					X			X			X					X	
58			X			X				X				X						X
59				X			X				X				X		X			
60				X		X					X					X			X	
61				X			X				X					X				X
62				X			X				X				X			X		
63				X		X						X				X				
64				X				X				X			X					
65				X		X					X					X				X
66				X				X			X					X			X	
67				X				X		X						X			X	
68				X			X					X				X		X		
69				X		X			X						X			X		
70				X				X				X				X		X		

Figure 14 (cont'd)

Quartile Distribution of Individual Averages for All Paces

No.	Incentive Q_1	Incentive Q_2	Incentive Q_3	Incentive Q_4	Normal Q_1	Normal Q_2	Normal Q_3	Normal Q_4	Free Choice Q_1	Free Choice Q_2	Free Choice Q_3	Free Choice Q_4	Fastest Q_1	Fastest Q_2	Fastest Q_3	Fastest Q_4	Slowest Q_1	Slowest Q_2	Slowest Q_3	Slowest Q_4
71				X			X					X			X					X
72				X				X			X					X			X	
73				X				X								X			X	
74				X			X			X						O		X		
75				X				X				X				O			X	
76				O		X						X				X				X
77							X											X		
78									X										X	

Figure 14 (cont'd)

Quartile Distribution of Industrial Averages for all Paces

Scatter Diagrams Showing Correlation between Individual Performances at Different Rates. Individual Times are Paired.

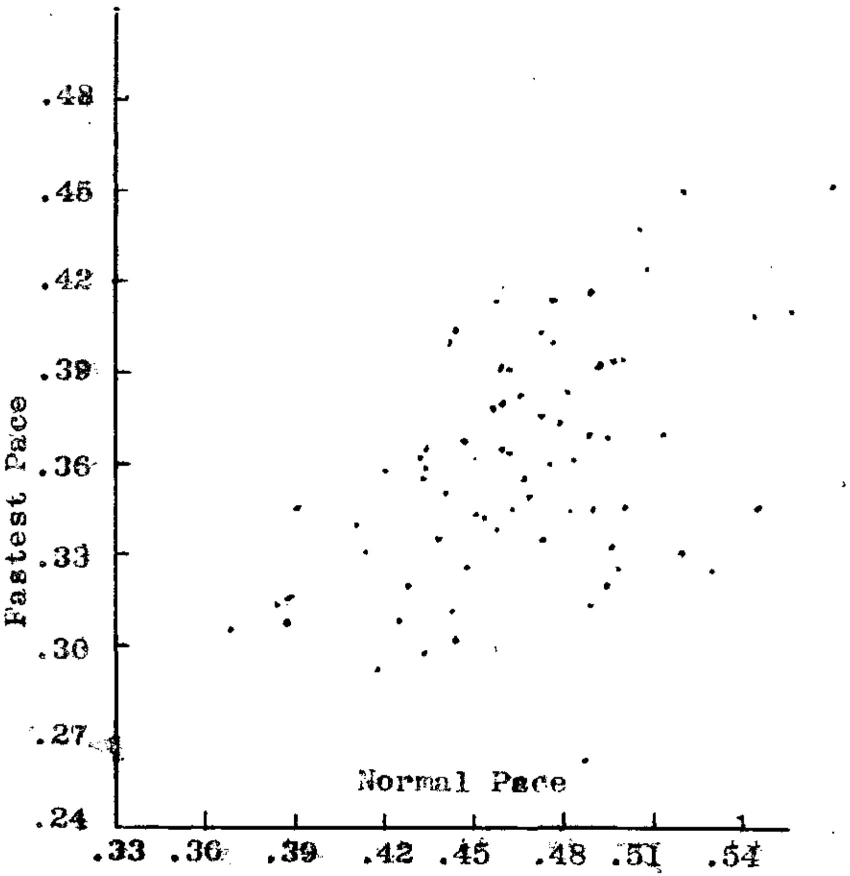


Figure 15

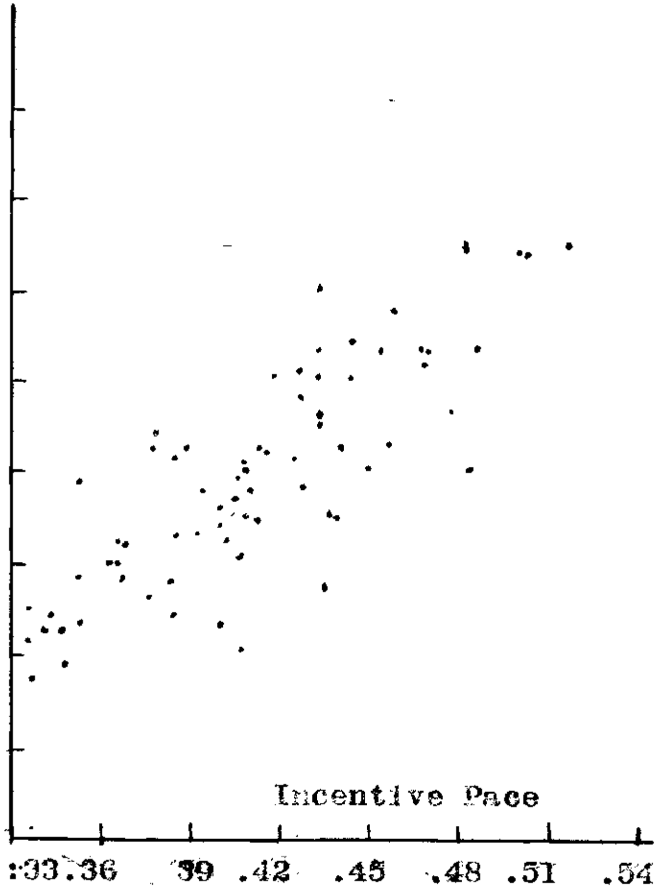


Figure 16

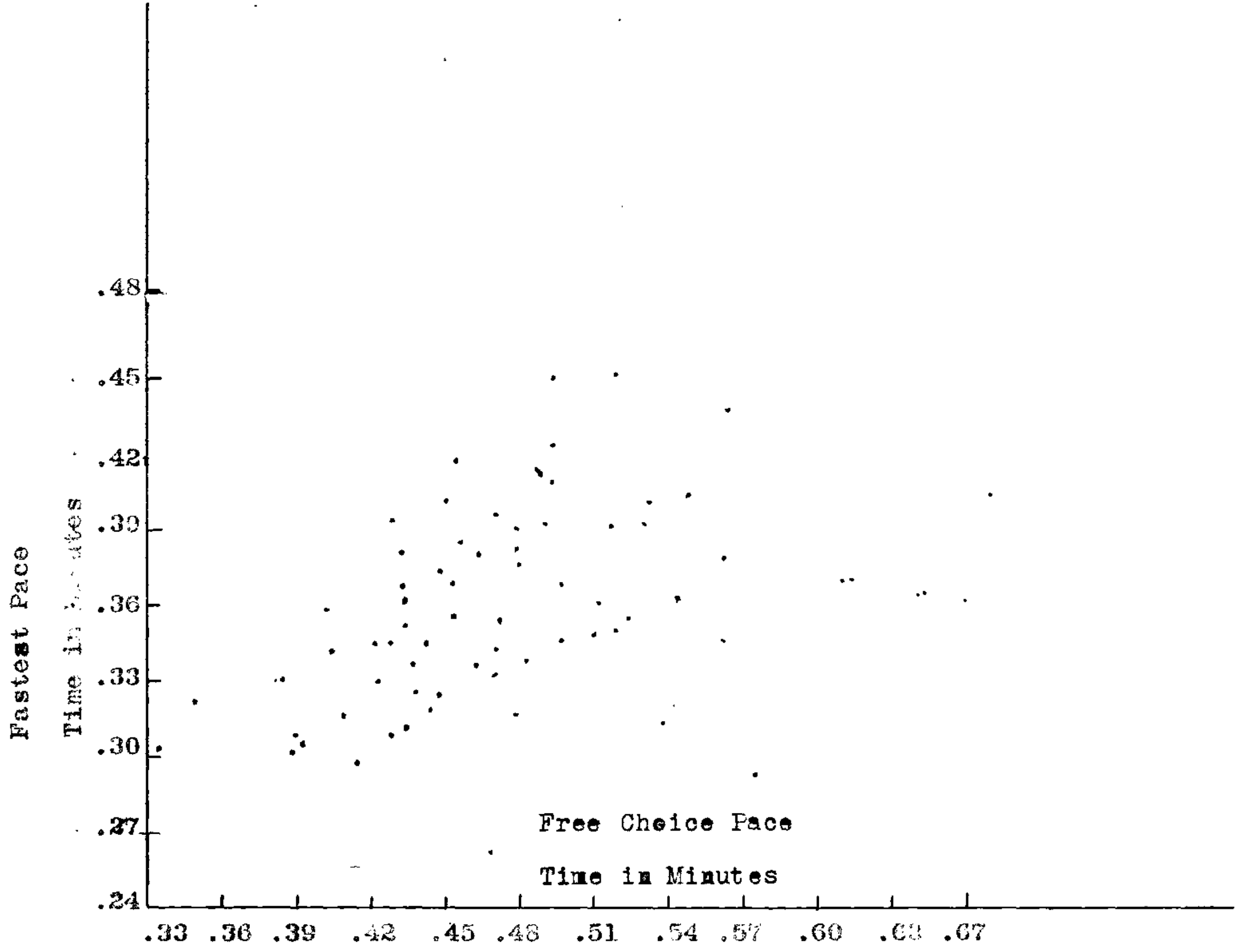
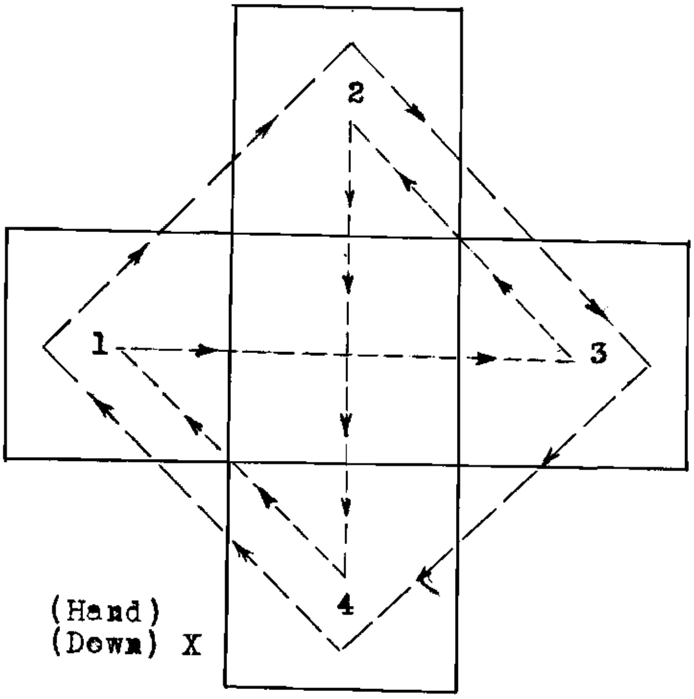


Figure 17 - Scatter Diagram Showing Correlation between Individual Performances at Different Rates. Individual Times are Paired.



Box Dimensions: 7" Square
Straight Rotation — —
On Diagonals -----

Figure 18 - Diagram of Test Setup